Defence Research and Development Canada · Recherche et développement pour la défense Canada

DEFENCE R&D DÉFENSE

Evaluation of soil contamination by explosives and metals at the Land Force Central Area Training Centre (LFCA TC) Meaford, Ontario (Phase I)

Guy Ampleman, Sonia Thiboutot, André Marois, Annie Gagnon
DRDC Valcartier

Defence R&D Canada – Valcartier
Technical Report
DRDC Valcartier TR 2008-390
May 2009

Canada

Evaluation of soil contamination by explosives and metals at the Land Force Central Area Training Centre (LFCA TC) Meaford, Ontario (Phase I)

Guy Ampleman, Sonia Thiboutot, André Marois, Annie Gagnon
DRDC Valcartier

Defence R&D Canada – Valcartier

Technical Report
DRDC Valcartier TR 2008-390
May 2009

Principal Author

Original signed by Guy Ampleman

Guy Ampleman

Defence Scientist

Approved by

Original signed by Pierre Lessard

Pierre Lessard

Section Head/ Energetic Materials Section

Approved for release by

Original signed by Christian Carrier

Christian Carrier

Chief Scientist

This work was sponsored by Director Land Environment and Director General Environment

Abstract

This work describes the first evaluation of the impacts of the live fire training at the Land Force Central Area Training Centre (LFCA TC) Meaford, Ontario (Phase I). This study was conducted in September 2007 by DRDC Valcartier for Director Land Environment (DLE) to evaluate soil contamination by explosives and metals. In parallel, the Institut national de la recherche scientifique (INRS) conducted sampling and analysis of surface water and groundwater for metals and explosives and produced a separate report describing their results. In our study, most of the ranges at LFCA TC Meaford were sampled during the September 2007 campaign. Seventeen ranges were sampled to evaluate the explosives and/or metals contamination. More precisely, at the small arms ranges, skeet range, artillery firing positions, anti-tank, grenade and other ranges, 135 soil samples were collected and analysed, including 79 for energetic materials, 56 for metals and seven for polycyclic aromatic hydrocarbons (PAHs) analyses. Surface and groundwater samples (35) were collected by INRS, analysed by DRDC Valcartier and revealed no energetic materials. Twenty soil background samples were taken for the metals evaluation for comparison purposes. Soil samples collected from Apeldorn, Cambrai, Ortona, Paardeburg Anti-tank, the Urban Assault and Skeet Ranges, as well as all the small arms ranges: Gully, Alpha and Gravenstafel Ridge; were analysed for metals contamination. Metal analyses were done using Inductively Coupled Plasma /Mass Spectrometry (ICP/MS) and explosives concentrations were determined using the High Pressure Liquid Chromatography (HPLC) Method EPA 8330b. The results showed that some firing positions are contaminated by energetic materials at low concentrations. Surprisingly, some firing positions contained metals at values higher than the industrial human health risk threshold criteria of the Canadian Council of Ministers of Environment (CCME). Tank positions in Cambrai were highly contaminated by selenium. All the small arms ranges contained lead at high concentrations while the skeet range contained PAHs at values higher than the CCME industrial threshold criteria. More work is needed to clarify the situation, especially for the tank positions in Cambrai and will be conducted during Phase II. This report describes the sampling and the results obtained during this study.

Résumé

Ce travail décrit la première évaluation des impacts de l’entraînement de tir réel faite au Centre d’instruction du Secteur du Centre de la Force terrestre (CISCFT) à Meaford, en Ontario (Phase I). Cette étude a été effectuée en septembre 2007 par RDDC Valcartier pour le Directeur Environnement de l’armée de terre (DEAT) afin d’évaluer la contamination des sols par les explosifs et les métaux. En parallèle, l’Institut national de la recherche scientifique (INRS) a effectué l’échantillonnage de l’eau de surface et souterraine pour les métaux et les explosifs et produit un rapport séparé décrivant ces résultats. Dans notre étude, la plupart des secteurs du CISCFT Meaford ont été échantillonnés pendant la campagne de septembre 2007. Dix-sept secteurs ont été échantillonnés pour évaluer la contamination par les explosifs et/ou par les métaux. Plus précisément, dans les secteurs des petits calibres, de tir au pigeon d’argile, de positions de tir d’artillerie, d’anti-char, de grenades et autres, 135 échantillons de sol ont été recueillis et analysés, incluant 79 pour les matériaux énergétiques, 56 pour les métaux et sept pour les hydrocarbures aromatiques polycycliques (HAP). Des échantillons d’eau de surface et souterraine (35) qui ont été recueillis par l'INRS et analysés par RDDC Valcartier n'ont révélé aucun matériau énergétique. Vingt échantillons de sols d'arrière-plans ont été recueillis pour analyser les métaux et servir de comparaison. Les échantillons de sols recueillis dans les secteurs Apeldorn, Cambrai, Ortona, anti-char Paardeburg, Assault Urbain et tir au pigeon d'argile aussi bien que dans tous les secteurs des petits calibres Gully, Alpha, Gravenstafel Ridge ont été analysés pour la contamination par les métaux. Les analyses de métaux ont été effectuées par plasma inductif couplé/spectrométrie de masse (PIC/SM) et les concentrations d'explosifs ont été déterminées par la méthode de chromatographie liquide haute pression (CLHP) EPA 8330b. Les résultats ont montré que quelques positions de tir sont contaminées par des matériaux énergétiques à des concentrations basses. Étonnamment, quelques positions de tir contenaient des métaux à des valeurs supérieures au critère de niveau industriel pour les risques à la santé humaine du Conseil canadien des ministres de l'Environnement (CCME). Les positions des chars dans Cambrai étaient très contaminées par le sélénium. Tous les secteurs des petits calibres contenaient du plomb à des concentrations élevées, alors que le secteur de tir au pigeon d'argile contenait des HAP à des valeurs supérieures au critère industriel CCME. Du travail supplémentaire est nécessaire pour préciser la situation, plus particulièrement aux positions des chars dans Cambrai, ce qui sera accompli durant la phase II. Ce rapport décrit l'échantillonnage utilisé ainsi que les résultats obtenus durant cette étude.

Executive summary

Evaluation of soil contamination by explosives and metals at the Land Force Central Area Training Centre (LFCA TC) Meaford, Ontario (Phase I):

Guy Ampleman; Sonia Thiboutot; André Marois; Annie Gagnon; DRDC Valcartier TR 2008-390; Defence R&D Canada – Valcartier; May 2009.

Introduction or background: The international context of demilitarization, the closure of military bases and the more stringent aspects of environmental laws have led to the establishment of new areas for research and development. Many activities of the Canadian Forces such as the firing of ammunition and the destruction of obsolete ammunition by open burning and open detonation may lead to the dispersion of energetic compounds and other munitions-related contaminants in the environment. It is within this context that Defence Research and Development Canada - Valcartier (DRDC Valcartier) and the US Army Engineer Research and Development Center (ERDC), Cold Regions Research and Engineering Laboratory (CRREL) and the ERDC Environmental Laboratory (EL) initiated research programmes to study the environmental impacts of energetic materials that are found in ammunition. The site characterization allowed the development of a unique expertise and positioned our departments to better understand the impacts of live fire training and to be in a readiness state to answer any inquiries and take corrective actions, if needed. The first training areas to be characterized were mainly army bases such as CFB Chilliwack, Shilo, Valcartier, Gagetown in Canada and, Fort Bliss, Fort Lewis, Yakima, MMR and many others in the United States. The Canadian programme was sponsored by DRDC, DGE, DLE and by a major US Department of Defense (DoD) funding program, the Strategic Environmental R&D Program (SERDP). Considering that LFCA TC Meaford will be extensively used in the future, DRDC Valcartier was tasked by Director Land environment (DLE) to evaluate the contamination by explosives and metals in soils of the ranges in Meaford. At the same time, the Institut national de la recherche scientifique (INRS) conducted surface water and groundwater sampling for explosives and metals analyses and produced a separate report describing their findings.

Results: Most of the ranges at LFCA TC Meaford were sampled during the September 2007 campaign. More precisely, at the small arms ranges, skeet range, artillery firing positions, anti-tank, grenade and other ranges, 135 soil samples were collected including 79 for energetic materials, 56 for metals and seven for polycyclic aromatic hydrocarbons (PAHs) analyses. Metal analyses were done using Inductively Coupled Plasma /Mass Spectrometry (ICP/MS) and explosives concentrations were determined using the High Pressure Liquid Chromatography (HPLC) Method EPA 8330b. The results showed that some firing positions were contaminated by energetic materials at low concentrations. Surprisingly, some firing positions contained metals at values higher than the CCME human health risk industrial threshold criteria. Tank positions in Cambrai were highly contaminated by selenium. All small arms ranges contained lead at high concentrations, while the skeet range contained PAHs at values higher than the CCME industrial criteria.

Significance: These results indicated that live firing and training activities may lead to the contamination of soils by explosives and metals at significant concentrations. Nevertheless, the Meaford training area is now considered not contaminated and may be used for training purposes. An important aspect of training area characterization is the water surveillance programme that is put in place following the hydrogeological study. The public has very low acceptance for water contamination by explosives and metals in water are strictly regulated. It is therefore of high significance to conduct these characterizations and understand the explosives and metal contamination on the Canadian Forces bases.

Future plans: More work is needed to clarify the situation in specific areas of this base and will be conducted during Phase II.

Sommaire

Evaluation of soil contamination by explosives and metals at the Land Force Central Area Training Centre (LFCA TC) Meaford, Ontario (Phase I):

Guy Ampleman; Sonia Thiboutot; André Marois; Annie Gagnon; DRDC Valcartier TR 2008-390; R & D pour la défense Canada – Valcartier; Mai 2009.

Introduction ou contexte: Le contexte international de la démilitarisation, de la fermeture de bases et de la sévérité croissante des lois environnementales a entraîné l'émergence de nouveaux champs de R et D. Plusieurs activités des Forces canadiennes, telles que l'entraînement au tir de diverses munitions et la destruction de munitions par brûlage ou détonation extérieure peuvent conduire à la dispersion de matériaux énergétiques et d'autres contaminants dans l'environnement. C'est dans ce contexte que Recherches et développement pour la défense Canada - Valcartier (RDDC Valcartier) en collaboration avec Cold Regions Research and Engineering Laboratory (CRREL) et Environmental Laboratory (EL) de l'US Army ERDC, ont entrepris des programmes de recherches afin d'étudier les impacts environnementaux des composés énergétiques que l'on retrouve dans les munitions. La caractérisation des sites a permis de développer une expertise unique et a positionné nos organisations de façon à mieux comprendre les impacts des entraînements au tir réel et à être prêtes à répondre à toutes les éventualités pour prendre des mesures correctives, si nécessaire. Les premiers sites d'entraînement à être évalués ont été des bases de l'armée, telles que BFC Chilliwack, Shilo, Valcartier, Gagetown au Canada et Fort Bliss, Fort Lewis, Yakima, MMR et plusieurs autres aux États-Unis. Le programme canadien a été financé par RDDC, DGE, DEFT ainsi que par un programme majeur de fonds américain, le Strategic Environmental R&D Program (SERDP). Compte tenu que CISCFT Meaford sera davantage utilisé dans le futur, RDDC Valcartier a été mandaté par le Directeur Environnement de l'armée de terre (DEAT) pour évaluer la contamination par les explosifs et les métaux dans les sols des secteurs à Meaford. En même temps, l'Institut national de la recherche scientifique (INRS) a effectué l'échantillonnage de l'eau de surface et souterraine pour les métaux et les explosifs et produit un rapport séparé décrivant ces résultats.

Résultats: La plupart des secteurs du CISCFT Meaford ont été échantillonnés pendant la campagne de septembre 2007. Plus précisément, dans les secteurs des petits calibres, de tir au pigeon d'argile, de positions de tir d'artillerie, d'anti-char, de grenades et autres, 135 échantillons de sol ont été recueillis, incluant 79 pour les analyses de matériaux énergétiques, 56 pour les métaux et sept pour les hydrocarbures aromatiques polycycliques (HAP). Les analyses de métaux ont été effectuées par plasma inductif couplé/spectrométrie de masse (PIC/SM) et les concentrations d'explosifs ont été déterminées par la méthode de chromatographie liquide haute pression (CLHP) EPA 8330b. Les résultats ont montré que les positions de tir étaient contaminées par des matériaux énergétiques à des concentrations basses. Étonnamment, quelques positions de tir contenaient des métaux à des valeurs supérieures au critère industriel de risques pour la santé humaine du Conseil des ministres de l'Environnement (CCME). Les positions des chars dans Cambrai étaient très contaminées par le sélénium. Tous les secteurs des petits calibres contenaient

du plomb à des concentrations élevées alors que le secteur de tir au pigeon d’argile contenait des HAP à des valeurs supérieures au critère industriel CCME.

Importance: Ces résultats indiquent que le tir réel et les activités d’entraînement peuvent entraîner la contamination des sols par les explosifs et les métaux à des concentrations importantes. Néanmoins, la zone d'entraînement de Meaford est désormais considérée comme non contaminée et peut être utilisée pour l’entraînement. Un aspect important de la caractérisation des secteurs d'entraînement et de l’eau souterraine est la mise en place d’un programme de surveillance suite à l'étude hydrogéologique. La population accepte difficilement la contamination de l'eau souterraine par des explosifs et les métaux dans l'eau sont strictement réglementés. Il est donc de la plus haute importance de procéder à ces caractérisations et de comprendre la contamination par les explosifs et les métaux sur les bases des Forces canadiennes.

Perspectives: Il faudra travailler davantage pour préciser la situation de certaines régions de cette base, ce qui sera accompli durant la phase II.

Table of contents

List of figures

List of tables

Acknowledgements

The authors wish to thank the Director Land Environment and Director General Environment for their financial support and vision. The authors also wish to thank Defence Construction Canada (DCC) for their support during this surface characterization. More precisely, the authors wish to acknowledge the excellent work performed by Mr. Daniel Bérubé from DCC who was responsible for all of the analytical supplies and metal analyses during the field work in Meaford. Range Control Canadian Forces personnel of LFCA TC Meaford are especially thanked for their invaluable help, openness, description of the ranges and support in all these sampling events. More precisely, we would like to thank Mr. Ted Keunecke, the Environmental Officer, who gave us all the support and provided references needed to accomplish our task. Mr. Keunecke also accepted to serve as reviewer for this report and the authors wish to thank him for his excellent work. We also wish to thank all personnel of range control at the LFCA TC Meaford who helped us, more particularly the Range Control Officer, RCO Capt. Paul Gillman, the Range Control warrant officer, RCWO Mike Thompson, Sgt Daniel Glenighan and finally, Cpl Jay Foster.

1 Introduction

Energetic materials and metals are prominent components of munitions and weapons that can be found in war zones, training ranges and on production sites. During the last decade, many needs emerged related to the identification, quantification, delimitation and elimination of energetic contaminants dispersed by munitions, or present in explosives dumps, trials or destruction fields, firing areas and production sites. Within this context of growing awareness of environmental issues, Defence Research and Development Canada, through DRDC Valcartier, has directed some of its resources to assess and develop expertise related to the environmental risks associated with explosive compounds. Metallic debris also represents an important issue for DND since live firing of munitions is spreading significant quantities of metals that are strictly regulated by law.

Many Canadian Forces sites used as impact areas, training ranges, demolition and open burning/open detonation (OB/OD) ranges, which were used to destroy obsolete materials, were highly suspected of being contaminated with energetic substances as described in the literature (Refs. 1-14). To evaluate the contamination of Department of National Defence (DND) sites, sampling and characterization of various ranges were performed over the last fifteen years (Refs. 1, 2, 13-16). A protocol was developed and describes the different methods of sampling and the analytical chemistry (Ref. 17). This protocol was updated in collaboration with the US Army Corps of Engineers, Cold Regions Research and Engineering Laboratory (CRREL) and reviewed under the auspices of the Technical Cooperation Program (TTCP) by the member nations (Canada, U.S., U.K., Australia and New Zealand) in a key technical area (KTA 4-28) (Ref. 18). The last version of this protocol can be found on the web at: http://www.em-guidelines.org/ener.htm. Up to now, research has demonstrated that explosives are not common contaminants, since they exhibit limited aqueous solubility and are dispersed in a heterogeneous pattern of contamination. In Canada and in the United States, Many efforts have been put into developing analytical chemistry, to establish the best sampling procedure and to understand the complex fate of explosives in the environment (Refs. 3-12, 18-27).

DRDC Valcartier has collaborated with CRREL and the US Army Corps of Engineers, Environmental Laboratory (EL) in Vicksburg to evaluate the environmental impacts of live-fire training, to characterize and mitigate adverse effects on training ranges and thereby sustain the military activities (Ref. 28). Lately, more efforts were undertaken to assess the environmental loading of explosives at most of the Canadian Forces Bases (CFB). To date, these efforts addressed mainly heavily used target areas (Refs. 13-16, 29-40). Walsh et al (Ref. 10) observed that the firing positions were also experiencing a build-up of energetic residues, and since then, a lot of studies have been dedicated to the characterization of the firing positions (Refs. 39, 41). It was determined that NG and/or 2, 4-dinitrotoluene (2,4-DNT) embedded in nitrocellulose fibres are deposited in front and around firing positions (Refs. 31, 40-42).

Following that, DRDC Valcartier assessed the dispersion of propellant residues following 105-mm artillery and tank gun firings at CFB Valcartier by placing aluminium witness plates in front of the muzzles of the guns (Ref. 43). At CRREL, similar trials were conducted using snow as a collection media (Ref. 44). Both studies demonstrated that propellant residues comprised of nitrocellulose fibres containing 2,4-DNT were deposited in front of the muzzle of artillery guns but no residues were found after firing tank ammunition in Valcartier (Ref. 43). More recently, Ampleman et al. confirmed that 0.2 - 0.5% of 2,4-DNT is ejected at the muzzle of the gun during artillery firings in open atmosphere and inside a muffler in Nicolet (Ref. 45). Ampleman et al. confirmed that tank gun firing resulted in no residues expelled by the 105 mm gun (Ref. 46). This was explained by the fact that 105 mm tank gun munitions contained more propellants than the 105 mm artillery gun munitions reaching a higher pressure and temperature in the tank gun, leading to a better combustion. More recently, Walsh et al. studied residues at mortar firing positions (Ref. 47) and NG was found at elevated concentrations for 81-mm mortars. Finally, Thiboutot et al. found that firing shoulder weapons such as the Karl Gustav 84 mm may leave up to 14% of nitroglycerine at the firing positions (Ref. 48). Now, more efforts are dedicated at sampling firing positions for all military activities.

To better assess the contamination and characterize an area, an appropriate definition and understanding of the hydrogeological context of the site is required. Characterizing the groundwater quality, especially on large ranges, is critical because metals and energetic materials are mobile in sandy environments and may migrate in groundwater, presenting a threat to human health and to the environment. Since most of the CFBs in Canada are located in sandy environments, groundwater flow has to be carefully assessed by determining its velocity and direction. The quality of the groundwater also has to be evaluated since it is often used for irrigation purposes, as a drinking water source by the base and to sustain aquatic ecosystems. In LFCA TC Meaford, the geology is rock and sands that are found close to the edge of the Georgian Bay, consequently, the groundwater discharges into Georgian Bay, a highly sensitive area for wildlife and human receptors. The first phase of the hydrogeological study was completed by INRS in September 2007 and all the results from this study will be reported later. The complete description of the geology can be found in that report. The second phase of the hydrogeological study will take place in June-September 2008 and will include the drilling of new wells.

This report describes the strategy used in the sampling and the results obtained during the surface soil sampling study that was conducted in September 2007 and called Phase I. This study was performed by DRDC Valcartier for the Director Land Environment who sponsored the entire study. Defence Construction Canada (DCC) was responsible for hiring the analytical laboratory, providing manpower, logistics and making the link with range control personnel.

2 Range Description and History

Land Force Central Area Training Centre Meaford (LFCA TC Meaford) is a Canadian Forces training facility operated by Land Force Central Area (LFCA) of Land Force Command (LFC). It is located in Grey County, Ontario, northwest of the Meaford townsite and approximately 25 km east of Owen Sound on a peninsula extending into Georgian Bay. Relatively few military personnel are stationed at the training centre as it serves primarily for training regular force and Primary Reserve units stationed within LFCA.

Camp Meaford was acquired in 1942 by the Department of National Defence which purchased 68 km^2 (17,500 acres) of private lands along Georgian Bay in the St. Vincent Township. The southern edge of this property is 5 km northwest of the town of Meaford and its western boundary is 15 km northeast of the city of Owen Sound. The property is centred on Cape Rich, a headland extending into Georgian Bay which divides Owen Sound from Nottawasaga Bay. The Meaford Military Camp (also known as Camp Meaford) was intended for tank warfare and artillery gunnery training. LFCA TC Meaford was ideal for this training since it incorporated limestone cliffs, rolling open ground and dense bush. The area was also interspersed with a year round swamp, a lake and 22 kilometres of shoreline to the east and north. The "Meaford Training Area" quickly became known as "The Tank Range" and became an annex to what was then known as Camp Borden.

From its inception during World War II until the late 1960s when the Canadian Forces were unified, Camp Meaford was used extensively by regular force Canadian Army units assigned to Camp Borden. It hosted many schools for exercises and driver training. The most prominent users were the Royal Canadian Armoured School and the Royal Canadian School of Infantry. Other schools, the fore runners of the present Canadian Forces Schools of Intelligence and Security, Administration and Logistics, and Medical Services also made frequent use of the Camp Meaford facilities for exercises and driver training.

The integration of the modern-day Canadian Forces saw the transfer of the Combat Arms School from CFB Borden to CFB Gagetown in 1969-1970, dramatically reducing the requirement for Camp Meaford. In 1970, it was decided to mothball the entire facility, reducing staffing from 153 military and civilian personnel to a five person security staff of Commissionaires. With the exception of these Commissionaires at the main entrance, no military person set foot within the camp boundaries until the early seventies. At that time, units of the Canadian Forces Primary Reserve began to make unofficial use of this large DND property only 180 kilometres north of Toronto, rather than face the 380-kilometre drive to CFB Petawawa for training.

In 1973, a National Defence Headquarters (NDHQ) study concluded that manoeuvres and live firing could be conducted at Meaford by elements of the regular force and the militia and cadets based in southern and central Ontario. This offered considerable cost savings primarily in transportation compared to having these units travel to CFB Petawawa or other sites. Authority was received to reopen Meaford as a training area. With its reopening in 1973, the use of Meaford by regular, reserve, militia, cadet and police forces for live firing and training has been increasing.

The cancellation of projects to support the Armoured Vehicle General Purpose (AVGP), the six-wheeled COUGAR and GRIZZLY training at CFB Petawawa by 1981/82 made Meaford the only physical area in Central Region capable of supporting the COUGAR's 76 mm gun for live fire training. This factor alone affected the operational efficiency of one regular force and six militia armoured regiments. It is also the only dry manoeuvre area in the same geographical region capable of supporting all arms combat team training a factor which impacts on one regular force formation and up to 42 militia units in Ontario. Moreover, the Meaford Range and Training Area (MRTA) saw increased use through the late 1980s and early 1990s as the Canadian Forces Primary Reserve began to increase in numbers when in September 1988, it was announced that MRTA would be renamed Militia Training and Support Centre, Meaford (MTSCM) and would become the focal point for training all reserve units in Ontario.

Recognizing a need, the Department re-activated the camp in August 1989 and a small cadre of regular and reserve force soldiers and kitchen staff began to operate the facility on a full time basis. The creation of MTSCM saw all buildings and areas of the camp reactivated and a small number of personnel and civilian employees stationed at the facility full time. By 1995, over $80 million in new construction for buildings, roads, waterworks and sewage disposal had taken place. Over $20 million in equipment and supplies were positioned at MTSCM to complement its training and support role. Construction of the facility was completed within a two-year period and today the Centre is considered to be state of the art. Its primary purpose is to revolutionize the training of reserves.

A mid-1990s reorganization of the Canadian Forces saw Force Mobile Command redesignated Land Force Command, with its units across Canada divided geographically. The newly created Land Forces Central Area redesignated MTSCM into Land Force Central Area Training Centre Meaford (LFCA TC Meaford).

LFCA TC Meaford is currently the primary training centre for Land Forces Central Area's reserve units. Regular Force units from CFB Petawawa (and formerly from CFB London) are also major users of the facility. The training centre conducts year round courses for regular force personnel, while expanding dramatically during the summer months to accommodate a large number of courses for reserve personnel. During the period of September-June, LFCA TC Meaford serves as the primary weekend training location for reserve unit exercises for units from the Greater Toronto Area and other locations across Southern Ontario. LFCA TC Meaford currently holds basic qualification courses as well as infantry and artillery training. It is visited by various outside units including multiple police forces and other nations. It also provides modern simulators and training for urban environments.

LFCA TC Meaford now has a permanent staff of nearly 300 military and civilian personnel of DND and Canadian Base Operators (CBO). In-house training courses may see up to 150 students living on the base. Reserve Force units train on weekends from September through May, and up to a dozen units comprised of 1000 personnel may be present at once to train on the ranges, facilities and vehicles maintained by the Training Centre. In the summer months, a high level of intensity is achieved with Area Reserve Courses (ARC) for Ontario Reserve personnel. During this period, the training centre population can exceed 2000 students and staff.

In this context of increasing use of the land, Director Land Environment asked for a complete characterization of the soils for explosives and metals and also for a complete hydrogeological study of surface water and groundwater to evaluate if the intense use will be leading to an increase of the contamination by explosives and metals. To realize this hydrogeological study, many wells will be installed in 2008 and will serve as a surveillance tool for DND.

3 Experimental

3.1 Contractors Involved

Defence Construction Canada (DCC) was responsible for hiring the analytical laboratory and for supplying all of the analytical tools, solvents, bottles, etc., for the analyses of metals. They were also responsible for making the link between DRDC Valcartier and range control and other responsible personnel at LFCA TC Meaford. DCC was also responsible for the shipment of all samples to the laboratories. The analytical work for metals was sub-contracted to Maxxam Analytical Inc. in Mississauga, Ontario. All the energetic materials analyses were performed by DRDC Valcartier which provided the coolers and materials for this sampling.

3.2 Sample Handling and Treatment

Explosives are not volatile compounds and therefore, no specific precautions such as the use of sealed containers had to be taken during sampling of media containing explosives. Soil samples were composited based on a minimum of 40 systematic sub samples and were stored in polyethylene bags. The bags were immediately stored on ice in coolers in the dark to avoid photo degradation of light-sensitive compounds. The use of polyethylene bags decreased the space needed for storing samples. Each day, the soil samples were transferred from the coolers to a refrigerator at -20°C and kept there until the last day before shipping. They were brought frozen in coolers by INRS to DRDC Valcartier. The soil samples that were analysed for metals were kept in the same manner until shipped by DCC to Maxxam Analytical Inc. for digestion and analysis. Surface water samples for energetic materials were kept cold in 1-L amber glass bottles, stabilized with sodium bisulfate (1.5 g) and brought to DRDC Valcartier by INRS for explosive analysis.

3.3 Parameters Monitored and Analytical Methods

Some soil samples were analysed for metals and others for energetic materials. A total of 135 soil samples were collected including 79 for energetic materials, 56 for metals and seven for PAHs analyses. Thirty-five surface water samples were collected by INRS and analysed by DRDC Valcartier for energetic materials. Metals were analysed by Inductively Coupled Plasma/Mass Spectrometry (ICP/MS) by Maxxam Analytical Inc. All of the parameters available by this method were included in the study. For soils and surface water samples, energetic materials were analysed at DRDC Valcartier using the Reverse Phase High Pressure Liquid Chromatography (RP-HPLC) USA EPA SW 846 Method 8330b, a method that can produce a 0.1 ppm detection limit. See the EPA Method 8330b found on their internet site (www.epa.gov) for a complete description of the HPLC method. The HPLC method was preferred over the Gas Chromatography/Electron Capture Detection method recently published since reproducible results with the GC/ECD Method were difficult to achieve (Refs. 24-25). In our study, the HPLC method gave a detection limit of 0.1 ppm for all analytes in the calibration curve and this detection limit was reduced to 0.02 ppm when the sample extracts were concentrated in a Zymark apparatus.

Soil samples were dried in a hood for 24 hours in the dark, homogenized by adding acetone to form a slurry which was then evaporated. Soils were sieved through 10-mesh sieves and extracted at DRDC Valcartier according to the following procedure. Ten grams of soil were put into an amber glass vial and mixed with acetonitrile (20 mL). A vortex was applied for one minute, followed by a sonication period of 18 hours in a cooling ultrasonic bath in the dark. The samples were left to settle for 30 minutes. Acetonitrile (2 ml) was decanted from the vial and diluted with water (2 ml) containing calcium chloride (1%). The solution was filtered on a 0.45-micron filter to get 1 ml of solution ready to inject into the HPLC.

Soil extracts were maintained at 4°C until analyzed by HPLC according to Method EPA 8330b. Analyses were performed with a HPLC Agilent HP 1100 equipped with a degasser G1322A, a quaternary pump model G1311A, an autosampler G1313A and a UV diode array detector model G1315A monitoring at 210, 220 and 254 nm. The injection volume was 20 µl and the column was a Supelcosil LC-8 (25 cm x 3 mm x 5 µm) eluted with 15:85 isopropanol/water (v/v) at a flow rate of 0.75 ml/min. The column temperature was maintained at 25^{o} C during the analysis. Standards and solvents were diluted 1:1, acetonitrile to water (0.5 ml Acn /0.5 ml water). When 10 g in 20 ml of acetonitrile were used for the soil extraction, the detection limit for this method was 0.100 ppm.

In order to obtain a lower detection limit at 0.02 ppm, we filtered and concentrated to dryness 10 ml of acetonitrile from the soil extract with a Zymark evaporator (model TurboVap LV) in a test-tube. Thereafter, we added 0.5 ml of water and 0.5 ml of acetonitrile and used this mixture as the extract to inject for the analysis.

The water samples were concentrated onto solid phase cartridges (Waters SepPak Vac 6 cc (500 mg) Porapak RDX) using a vacuum manifold and eluted off using a small volume of acetonitrile. Before use, the cartridges were conditioned to activate the porapak RDX packing material. The SPE cartridge pre-treatment consisted in washing with 15 ml of acetonitrile followed by 30 ml of reagent grade water. Then, one litre of sample was loaded into the Waters Porapak RDX phase cartridge. The flow rate was about 10 ml/min. The SPE cartridges were then dried by pulling full vacuum for a few minutes to remove residual water. Then, 5 ml of acetonitrile were loaded into the cartridge to elute the retained analytes. The vacuum pump was pulsed to start the flow and then stopped to let the acetonitrile drip through under gravity alone. The flow rate was about 1 ml/min. The concentrated extracts were diluted 1:1 (v/v) with reagent grade water, pipetted into autosampler vial, and analyzed using HPLC method 8330b. According to this procedure, our detection limit for water analyses was 1 ppb.

3.4 Sample Nomenclature

All soil samples were named according to the following labelling system:

First part: sample type

M-07: Meaford sampling campaign 07

Second part: Location by range or type

BG:	Background sample
US:	Unit Special
Norm:	Normandy
RC:	Road crossing
Cam:	Cambrai
Caen :	Caen
Dieppe :	Dieppe
PAT :	Paardeburg anti-tank
Cas :	Cassino
Fibua:	Fibua/Ortona
AGR:	Apeldorn grenade
Ort :	Urban assault range Northeast of Ortona
Pusan:	Pusan
Skeet:	Skeet range
SAR:	Alpha small arms range
GSR:	Gravenstafel Ridge small arms range
RG:	Gully small arms range
MES:	Messines

Third part: Identification of the sample source

Position number (ex. 1, 2 or 1-3)

Background location by number or

Type of sample (ex. T1 for tank 1) or

Firing positions (ex. FP 100m)

Fourth part: Identification of the sample

According to sampling strategy or position number on figures (ex. 0-5m behind pad) or DUP for duplicate

3.5 QA/QC

Quality assurance and quality control programs were included in this study. Background soil samples were collected outside ranges close to the roads surrounding the ranges. All these background samples were collected to get the most representative soil types in areas close to the ranges. Analyses were done twice for energetic materials (lab replicates). Ten percent of field replicates were also sent for analysis and were named duplicate samples for comparison. The contracted laboratory reported their QA/QC including surrogates and blanks, detection limits, and quantification limits. Trip blanks and field blanks were also included in the QA/QC plan.

3.6 Safety and Emergency Plan

The sampling of an UXO-contaminated area represents an increased level of risk for personnel. The Range Control Officers gave a safety briefing to people involved in the sampling program. This briefing explained the precautions to be taken to avoid contact with UXOs and also described the various types of UXOs that may be found on ranges. A safety and emergency plan was also put in place for any incident that could have occurred while sampling. This plan was under the responsibility of the LFCA TC Meaford Range Control unit. When on site for sampling, personnel were always accompanied by Range Control personnel who were equipped with radios to contact Range Control in case of an emergency.

3.7 Sampling Strategy

Background soil samples are critical to establish the anthropogenic contribution versus the natural contribution for all metal parameters. Background composite samples were collected randomly, in circles of approximately 10 metres diameter in different locations outside the ranges close to roads. A minimum of 30 sub samples were collected to form each background sample. A statistical analysis was conducted to identify a mean background concentration and to define a limit for a value that can be considered normal. Values at the extremities of the lognormal curve were identified. The limits were chosen for a probability of 97.72% (two times the standard deviation). The probability of finding a result with a value higher than this limit is 2.28 %. When the metals were not detected, a value at half of the detection limit was used for the data analysis.

The usual strategy for soil sampling was based on multi-increment systematic sampling around representative areas of each range. Usually, surface soils were collected at a depth of 0-5 cm. This strategy was used in previous studies on antitank ranges, which showed very distinct patterns of contamination around targets (Ref. 2). This strategy was used for all samples. In some instances, the linear transect strategy was used to collect soils in front of or behind the firing positions. This was accomplished to verify the pattern of dispersion of energetic materials in front of or behind the firing positions. The GPS locations were collected in most of the ranges and can be found in Table 1. Some GPS locations will be mentioned during the analysis of the results.

Considering that 17 ranges were sampled during phase I, it will be more appropriate to describe the approach site by site in the next section instead of giving a general procedure for all the sites.

4 Results and Discussion

In our evaluation of the results for the metals concentrations, we chose to compare values for each parameter to values encountered in the background samples. By doing so, we can evaluate if the concentrations of a particular contaminant is anthropogenic or not. GPS locations for each background sample can be found in Table 1. From the management point of view, this approach can be valuable, but the site owners want to know if there are problems, at which extent and what can be done to solve them. Scientifically, comparison with the background values is important since it allows the understanding of the first effects of the training activities on the environment and gives us plenty of time to react and possibly eliminate the effects of such activity by applying mitigation methods to the sources.

Our approach consisted in comparing all the results to background values first, then to the agricultural soil quality guidelines (ASQG) and finally to the Industrial Soil Quality Guidelines (ISQG) established by the Canadian Council of Ministers of the Environment (CCME) (see www.ccme.ca or the file annexed in Annex A on compact disk). Even if DND properties are not dedicated to agriculture, the ASQG represents the first official threshold value and if concentrations of a particular parameter are higher than the ASQG, this can raise important questions for the management of the sites. This was particularly true for sites such as WATC Wainright where cows were allowed to graze on the DND property during summer. The same rationale can be applied to the ISQG since the DND properties are not industries, but having concentrations higher than the ISQG can urge the Department to find and apply solutions for due diligence.

In our evaluation of the results, the mean values for background samples were the mean of all collected backgrounds for each parameter measured. When results lower than detection limits were encountered for specific parameters, half of the detection limit for that parameter was used for calculation of the mean value. The results obtained in training areas were compared to the mean value of the background to which was added twice the standard deviation. This allowed the selection of results having values greater than the background means, while being representative. Results are presented for each parameter instead of per sample to facilitate the analysis of trends for each parameter. Backgrounds were always tabulated first with mean, standard deviation, mean plus twice the standard deviation, and CCME threshold criteria values for each metal. Then, results for samples collected in the training areas were tabulated.

For metals that were not included in the CCME list, results were compared only to the mean values added to twice the standard deviation of all soil background samples. Such results exceeding this value were highlighted in blue in Tables 2-6. When metal concentrations were above the agricultural criteria, they were also compared to the industrial soil criterion, which is the most permissive criterion. When the values were above the agricultural but below the industrial criterion, the values were highlighted in green, when above the industrial criterion, the values were highlighted in red in the tables.

During Phase I, 135 soil samples were collected including 79 for energetic materials, 56 for metals and seven for PAHs analyses. Analyses for the following metals were conducted on the 56 soil samples: Al, Sb, As, Ba, Be, Bi, B, Ca, Cd, Cr, Co, Cu, Fe, Pb, Li, Hg, Mg, Mn, Mo, Ni, K, Se, Sr, Na, Ag, Ti, Tl, W, Sn, U, V, and Zn. Sampling for metal analyses was accomplished in nine out of the 17 ranges visited. This included: Apeldorn grenade range, Cambrai, Fibua on Ortona, Gravenstafel Ridge, Urban Assault, Paardeburg Anti-Tank, Gully, Alpha small arms range, and the Skeet range. No major environmental impacts related to the training activities were identified in these ranges. In soils, the accumulation of some heavy metals associated with ammunition was observed in some parts of ranges and in some occasions, concentrations were above the industrial criterion. Phase I results clearly demonstrated some problems associated with soil contamination and these soils will be re-sampled during Phase II to better understand the situation.

For the 79 soil samples analysed for energetic materials, 13 parameters were screened for explosives, including the most common explosives RDX, HMX and TNT, using the HPLC method. Analyses for energetics were done at DRDC Valcartier using the RP-HPLC EPA SW 846 Method 8330b with a detection limit of 100 ppb for most analytes except for DNB, tetryl and PETN, for which limits were slightly higher. When concentrations were low, we used a Zymark concentrator to lower the detection limit to 20 ppb. Most of the analyses were performed twice but when discrepancies were observed, the analyses were repeated three and sometimes four times to get reproducible results. In Tables 7-8, these analyses were given Lab numbers followed by A, B, C or D. When the two first A and B analyses were not similar, C and D analyses were repeated until reproducibility was observed. Most of the samples except the Paardeburg Anti-Tank samples that contained high levels of explosives were done using the Zymark concentrator to detect all the analytes at lower concentrations. These samples are identified by a “z” at the end of the lab number. In general, the results obtained using the Zymark are consistent with the standard HPLC results but they showed more analytes. In many occasions, we also collected duplicate samples to verify and validate our technique of sampling. Most of the time, the duplicate samples gave concentrations similar to the original samples.

For the purposes of this report, we can consider that energetic compounds fall into two classes, those that are related to propellants and those related to high explosives. Nitroglycerine (NG), dinitrobenzene (DNB), dinitrotoluene (DNT) and trinitrobenzene (TNB) are either major ingredients or impurities in various types of propellants such as those used in rocket motors. Usually, rockets use either double base propellants composed of nitrocellulose and nitroglycerine or a thermoset polymeric matrix based on hydroxyl-terminated polybutadiene containing ammonium perchlorate as the oxidizer. The single base propellants also contain DNT as a plasticizer and impurities such as DNB and TNB coming from photodegradation of TNT or coming from the synthesis of energetic materials that started from toluene containing benzene as an impurity.

Perchlorate analyses and other parameters such as turbidity, nitrite and nitrate analyses were performed for surface water samples. Because perchlorate analyses are expensive, they were done only for a few water samples and revealed no perchlorate. The water samples provided by INRS and analysed by DRDC Valcartier, revealed no energetic materials either showing a good quality for surface water and groundwater. The surface water and groundwater results will be discussed in more detail in the INRS report.

High explosives used by both Canada and the United States generally contain either TNT (2,4,6-trinitrotoluene) or mixtures of TNT with RDX (hexahydro-1,3,5-trinitro-1,3,5-triazine), HMX (octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine), or for some older muntitions, tetryl. Most of the air weapons contain TNT with aluminium (tritonal explosives). The most powerful weapons contain Composition B (TNT with RDX) or octol (TNT with HMX). When UXOs are found on sites, they are often blown in place (BIP) using C-4, a mixture of RDX with a polymer. These BIP operations often spread explosives into the environment (Ref. 11). On top of the most common explosives, the HPLC method can detect the metabolites and impurities of TNT such as the 4-ADNT, 2-ADNT, nitrobenzene, etc. Results for energetic materials in soil samples are presented in Tables 7 and 8. 1,3-Dinitrobenzene, 2, 3, and 4-nitrotoluene, 1,3,5-trinitrobenzene and tetryl were removed from table 8 since they were never detected in any samples.

As mentioned in the previous section, strategies used for each range were different according to the use of the range and will be discussed in details for each range. To make the discussion easier, description of the ranges and results for the ranges where metal analyses were done will be made first, followed by the description of the ranges where only energetic materials analyses were done.

4.1 Apeldorn Grenade Range

As for most of the grenade ranges, the Apeldorn grenade range was composed of a bunker and a flat area in front of the bunker where grenades are launched to explode (Fig. 1). Normally, this area is contaminated by energetic materials and metals so, the soil samples were collected for both metals and EM analyses. Seven samples were composited in front of the bunker at distances of 5, 10, 15, 20, 25 and 30 metres (Fig. 2) and were named M-07-AGR-0-5m, M-07-AGR-5-10m, etc. A duplicate sample was collected for the area between 10 and 15 m in front of the bunker. As usual, 50 sub-samples were collected to build the composite sample representing the area.

It can be seen in Tables 2-6 that, Cr, Pb, Mg, Ni, Ti, and Ba concentrations are higher than the BGL + twice the standard deviation (highlighted in blue) while Cu showed one value over the BGL and another one higher than the ASQGL highlighted in green in the area 10-15 m. Fortunately, this is the area where the duplicate sample was collected and this one showed only 22 ppm, a value below the BGL. On the other hand, Zn was found at values higher than the Industrial threshold criteria and this, for all samples. Concentrations for zinc varied from 988 to 2140 ppm that is 2.7 to six times higher than the CCME industrial threshold criteria. This will have to be re-sampled during Phase II to verify these results. Selenium was not detected in any samples but considering that in these cases we used half of the detection limit as the result, all samples were quoted at 2 ppm. Because these artificial values are higher than the ASQGL, all values are highlighted in green. This does not represent a problem since this is resulting from the data treatment and not from a contamination of the soils. It is strange though that ASQGL is lower than the detection limit for this analyte.

In Table 9, only three samples showed RDX as the only contaminant in the area 0-5 m and in the 10-15 m at concentrations of 0.12 and 0.04 ppm. The latest result was not reproduced in the Dup sample of the 10-15 m area showing that at these concentrations, it is easy to get a small particle that will produce a hit. Considering that grenades are filled most of the time with TNT or comp B, it is likely that these hits may come from a blow in place of a dud grenade using C-4. At this level, this site is not considered contaminated by energetic materials but the zinc presence must be further investigated and this will be done in phase II.

4.2 Cambrai Range

Cambrai, Dieppe and Caen ranges are very similar and served as firing positions for many types of weapons such as: 105 mm Leopard tank, LAV Cougar 76 mm, Grizzly for 25 mm medium calibre, 105 mm Howitzer artillery gun, mortars, etc. Most of them have a large concrete pad from where the firings are performed. In some occasions, excess artillery bags were burned on the pad but they seemed quite clean during our visit. These ranges are facing the impact area and at the end of the range, there is a large stop butt (Fig. 3). They are all located around the observation tower where shooting can be observed (Fig. 4).

Metal analyses were done only in Cambrai around the tanks (Fig. 5). If we look at Tables 2-6, Cr, Cu, Ag, Sr, Ti, W, U, Ba, Bi and B concentrations are above the BGL and indicated an anthropogenic accumulation. Most of these metals have concentrations well below the ISQGL so, this is not of big concern. Of particular interest, Sr, W and Bi are well over the BGL but there are no threshold criteria for these metals. Boron concentration is at 1.38 ppm around tank 2 close to the ASQGL. Thallium is also close to the ISQGL at 0.9 ppm around tank 1. Uranium is found around tanks at values 4-5 times higher than the BGL at 1.2 and 1.6 ppm, which could indicate past uses of depleted uranium weapons. Even if these values are not very high, they show clear tendencies of accumulation around tanks in Cambrai.

Hg, Mo, Se, As, Sn, Zn and Cd demonstrated concentrations higher than the ASQGL or the ISQGL. All the samples collected around both tanks showed Se, As, Zn and Cd at values higher than the ISQGL. These samples will be re-collected during Phase II in August 2008 to confirm this situation. Of particular interest, selenium was found at extremely high values of 9,020 and 33,200 ppm around the tanks. Zinc concentrations were also quite high at 2,320 and 994 ppm for T1 and T2.

For energetic materials in Cambrai, there were six wood firing positions. Looking at the tanks, the firing positions were numbered 1 to 6 from left to right. Composite samples were collected in front of and behind positions 1 to 3 and 4 to 6 and were named M-07-Cam 1-3-AV and M-07-Cam 4-6-AV for those in front of the firing positions and M-07-Cam-1-3-AR and M-07- 4-6-AR for those collected behind the firing positions. Composite samples were also collected around tanks, a triplicate around tank 1 and another sample around tank 2 (Fig. 5). If one looks at Table 8, it is observed that all samples around tanks 1 and 2 showed HMX at low concentrations. This is not surprising since it is known that HMX stays at the surface in anti-tank ranges for years (Ref. 2) This also indicates that shoulder type anti-tanks, probably 84 mm Karl Gustav, were used in this site. Nitroglycerine was detected also at low concentrations of 2.25-4.44 ppm around tanks 1 and 2. 2,4-DNT was also observed at low concentrations of 0.08-0.24 ppm but only around tank 1.

Surprisingly, HMX was detected in front of firing positions 1-3 at 0.14 and 0.40 ppm. There is no known explanation for this anomaly. All the firing positions contained nitroglycerine and 2,4-DNT at concentrations varying from 0.84 to 28.88 ppm for nitroglycerine and 0.15-3.94 ppm for 2,4-DNT. These are considered low levels of contamination and this confirms that some shoulder type weapons may have been used in this range. It is known that HMX stays on the ground around tanks when using Karl Gustav 84 mm and that nitroglycerine is ejected behind leaving high concentrations of NG on the ground around firing positions (Ref. 48). It is surprising that samples in front of the firing positions were the most contaminated, normally the nitroglycerine deposits behind the shooter. It is highly possible that when using Karl Gustav, the shooter stood in front of these positions. Nitroglycerine can also come from the firing of small and medium calibre weapons. 2,4-DNT may have been deposited with the firing of artillery guns using M1 as the propellant (ref. 45).

4.3 FIBUA on Ortona

This range located on Ortona is adjacent to the Urban Assault Range and contains three buildings simulating houses to be captured during urban conflict (Figs. 6-8). Since high explosives (C4) were used to open doors, it was decided to sample in front of front doors. Three composite samples were made from soils collected in front of front doors of the building (Fig. 7) and were analysed for metals and energetic materials. These samples were named M-07-FIBUA- 1, 2 and 3.

For metals, Cu, Pb, Mg, Na and Zn showed values higher than the BGL but well below the ASQGL. For Se, it was not detected in any samples. As already explained, in this case, we used half of the detection limit and since this value is higher than the ASQGL, all values are highlighted in green. This does not represent a problem since it is the result of the treatment of the data and not of a contamination of the soils. This situation is observed for all the other samples in Tables 2-6 and will no longer be considered. For energetic materials, no explosives were found in any samples except nitroglycerine that was found at concentrations of 0.24 to 1.74 ppm, which is considered very low. No action is required on this site.

4.4 Urban Assault Range

This range is located northeast of Ortona and is used to simulate detonation impacts on buildings and also for small arms. Usually, they place C-4 blocks on the side of the road that explode close to structures that imitate houses. (Figs. 8-9). There was also a railway track used to move targets for small arms. We visited the stop butt but since it was highly vegetated, no sampling was performed at this location (Fig. 10). Soil samples were collected around the four structures in the Urban assault range and were named M-07-ORT-1, 2, 3 and 4. These samples were analysed for metals and energetic materials.

In metal analyses, antimony was detected over the BGL concentration at 1.0 ppm. Lead was detected at values higher than the ASQGL in three samples and higher than the ISQGL for one sample. The concentration higher than the ISQGL was 735 ppm around structure 1. The three other structures demonstrated concentrations between 99 and 318 ppm that are higher than the ASQGL. Considering the levels of lead, it can be said that this site is not extensively used but the concentrations are going up. This situation should be monitored in two-three years to verify if the levels are rising. No energetic materials were detected in any of the samples and this is often encountered in small arms ranges.

4.5 Gravenstafel Ridge Small Arms Range

This is a small arms range that is mainly used for pistol, rifle and sniper with 7.62 mm ammunition firing. In April 2007, the firing positions were a grass covered area while the targets were composed of 12 sand areas that were not clearly defined (Fig. 11). During our sampling visit in September 2007, we found only 10 sand target areas which were sampled for metals and we also sampled the firing positions for energetic materials (Fig. 12). The soils in front of targets 1-5 and targets 6-10 were composited to make two samples named M-07-GSR-1-5 and 6-10. The soils in front of the corresponding firing positions 1-5 and 6-10 were composited and named M-07-GSR-FP-1-5 and 6-10 respectively.

In front of the targets, antimony was found in both samples at concentrations higher than the BGL at 1.0 and 1.9 ppm. Lead was found at concentrations higher than the ASQGL at 210 and 230 ppm. This site can be considered less contaminated than what we are used to see in extremely used small arms ranges. In the firing positions, we found nitroglycerine at concentrations of 9.62-16.49 ppm and 2,4-DNT at concentrations of 0.09-0.43 ppm. These values are very low. No action is required on this site except monitoring from time to time.

4.6 Gully Small Arms Range

This small arms range contains 24 numbered target sand areas and this site was cleaned in April 2005 since there were over 100,000 rounds present in the range (Fig. 13). Because the maintenance costs were extensive, a treatment was applied to transform the lead into lead sulphate that is supposed to be less soluble and can be considered stabilized. This treatment was done in April 2005. To verify this point, particular attention should be given to the INRS water survey work that will look into this specific range. Soils samples were collected in front of the target lines from six targets at a time. These samples were named M-07-RG-1-6, 7-12, 13-18 and 19-24 and analysed for metals. The firing positions were covered with grass but they were sampled at 100 m and 300 metres in areas corresponding to sets of 12 target positions. These samples were composited and named M-07-RG-FP-100m-1-12 and 13-24 and M-07-RG-FP-300m-1-12 and 13-24 respectively.

In front of the targets, Mg and Sb were found in all samples at concentrations higher than the BGL. Antimony showed one hit at 20.2 ppm, which is higher than the ASQGL and the three other concentrations close to the ASQGL. Magnesium has no threshold criteria but was found at 30,000-34,000 ppm slightly higher than the BGL. Lead was found at concentrations two to six times higher than the ISQGL at concentrations of 1220-4010 ppm. Copper concentrations exceeded ISQGL in most of the samples at 179 to 264 ppm. Tin was also found at concentrations higher than the ASQGL at values of 12-14 ppm in most of the samples.

For the energetic materials, we found nitroglycerine at the 100 and 300 m firing positions. At the 100 m position 1-12, the NG concentrations were 21.16 to 138.30 ppm and for position 100 m 13-24, the concentrations were 34.2 to 52.9 ppm. If we take into account that the lines were numbered from the range access road 1 to 24, it seems that the first 1-12 firing lines are more used than the farther 13-24 firing positions. For the 300 m position 1-12, NG was found at 1.94 and 3.11 ppm while the 300 m 13-24 position showed only one hit at 0.49 ppm. Considering this, the 100 m firing positions seem more used than the 300 m firing position. 2, 4-DNT was found only in the firing position 100 m 13-24 at concentrations of 0.26-0.37 ppm. These values are low. No action is required on this site except monitoring from time to time.

4.7 Alpha Small Arms Range

This is the largest small arms range in Meaford. It contains 36 firing lines and was opened four years ago (Fig. 14). Soil samples were collected in front of the targets from six targets at a time. These samples were named M-07-SAR-1-6, 7-12, 13-18, 19-24, 25-30 and 31-36 and analysed for metals. The firing positions were covered with grass but they were sampled by sets of nine firing lines at 100 m. These samples were composited and named M-07-SAR-FP-100m-1-9, 10-18, 19-27 and 28-36.

In front of the targets, Mg was found in all samples at concentrations higher than the BGL. Magnesium has no threshold criteria but was found at 33,000-36,000 ppm. Antimony showed two hits higher than the BGL at 3.9 and 4.1 ppm, one hit higher than the ASQGL at 23.0 ppm and three other concentrations higher than the ISQGL at values of 41.9-69.6 ppm. Curiously, titanium was found in most of the areas in front of targets at values higher than the BGL at 90-112 ppm. Silver was also identified in two samples at 0.3 ppm which was higher than the BGL. Lead was found at concentrations 1.5-10 times higher than the ISQGL at concentrations of 932-6140 ppm. Copper concentrations exceeded ISQGL in most of the samples at 132 to 207 ppm. Tin was found at concentrations higher than the ASQGL at values of 6-18 ppm in most of the samples. Lines 25-36 seem to be less used. This site can be considered less contaminated than what is found in other small arms ranges elsewhere.

For the energetic materials, we found nitroglycerine at the 100 m firing positions. Positions 1-9 and 10-18 seem the most used and contained NG at concentrations of 16.94 to 54.58 ppm and for positions 100m 19-27 and 28-36, the concentrations were 0.93 to 1.32 ppm, showing that these firing positions are less used. This is consistent with the fact that the metals concentrations are lower for these firing lines. 2,4-DNT was found only in the firing positions 1-18 at concentrations of 0.10-0.30 ppm. These values are low. No action is required on this site except monitoring every two-three years.

The contamination patterns of Alpha and Gully are very similar. The levels of lead, copper, magnesium, antimony and tin are almost the same. However, the levels of titanium are different. The Alpha site has been used for four years and it is unknown how long Gully has been used. When comparing the firing positions in Table 7, we realized that the concentrations of nitroglycerine are almost three times higher in Gully than in Alpha. This means that Gully was fired upon more than Alpha but the concentrations of metals are lower or at least very similar. The main conclusion is that the cleaning or treatment that was done on Gully did something positive on the metal concentrations in that range.

4.8 Skeet Range

The Skeet range is a small range that was used to shoot clay pigeon flying targets but it was closed and it became necessary to evaluate its contamination by metals but also by polycyclic aromatic hydrocarbons that are contained in the clay pigeons. In this range, the targets were shot from boxes on the ground and the shooter was aiming at them shooting them always in a certain direction. For these reasons, we sampled the surface in front of the shooting area and divided this area, using flags, into six sections (Figs. 16-17). These samples were named M-07-SKEET-1, 2, 3 to 6 and were analysed for metals and PAHs. Soil samples were also collected beside and behind boxes that contained the launcher and were called M-07-SKEET BL and were analysed for metals and PAHs. Finally, duplicate composite samples were collected at the firing positions and analysed for energetic materials (Fig. 18).

No metals were detected at values higher than the BGL in any samples collected at this range. PAHs analyses revealed that many of the parameters exceeded ASQGL and/or ISQGL. If one looks at Table 9, it can be seen that benzo (a) pyrene exceeded the ISQGL in three out of seven samples at concentrations varying from 0.11 to 1.40 ppm. Samples M-07-Skeet -2, 4 and 5 have no parameters exceeding any threshold except for sample 4 where benzo (a) pyrene exceeded the ISQGL. In the other samples 1, 3, 6 and back launcher BL, PAHs exceeding the ASQGL were found to be: benzo (a) anthracene (at 0.18-1.70 ppm), benzo (b/j) fluoranthene (at 0.51-0.80 ppm), benzo (k) fluoranthene (at 0.11 ppm), dibenzo (a,h) anthracene (at 0.24 and 0.30 ppm), indeno (1,2,3-cd) pyrene (at 0.11 and 0.20 ppm) and pyrene (at 0.17-1.10 ppm). The soils of this range will have to be dealt with according to known procedures in secure landfill for soils contaminated by PAHs. No energetic materials were detected in any of the samples collected at the skeet range.

4.9 Paardeburg Anti-tank Range

This range is used mainly for firing shoulder type weapons such as the 84 mm Karl Gustav and the M-72 anti-tank weapons. These two weapons differ mainly by the composition of their propellant but also by the design of the combustion chamber. In the M-72, ammonium perchlorate is added to give oxygen to the composition resulting in a better combustion. Furthermore, its combustion chamber is more confined and is equipped with a nozzle that allows the pressure and temperature to be higher. In the Karl Gustav 84 mm, the propellant is a double base containing nitroglycerine and nitrocellulose and ejects more residues at the firing positions than the M-72 because of its venture design (Ref. 48). The pressure and temperature of the combustion are probably lower resulting in more residues ejected at the firing positions. The site was also used for 40 mm grenade launching before the Cassino range was opened. The site had two firing pads that can accommodate four firing positions and an observation position (Fig. 19). There are three targets in the impact area, on the left, a steel plate named T1, a bunker in the middle named T2 and an old tank on the right side named T3 (Figs. 20-21). Soil samples were collected around the targets and were named M-07-PAT- T1, T2 and T3 and were analysed for energetic materials. M-07-PAT-T1 and T3 were analysed for metals. Soil samples were collected behind the firing positions according to Figure 21. Composite samples were built at specific distances behind the firing pad to evaluate the progression of explosive deposition at 0-5, 5-10, 10-15 and 15-20 m behind the firing positions. These samples were named M-07-PAT-FP A for the left position and B for the right position followed by 0-5, 5-10, etc.

Metal analyses around targets revealed that Al, Cr, Hg, Fe, Sb, Ag, Ba, Be, Bi and B have concentrations higher than the BGL values. Most of these values were well below the ASQGL indicating that there is a low anthropogenic impact. Pb, Sn, and Zn had values either over the ASQGL or the ISQGL. In general T3 is more contaminated than T1 and this is normal since T1 is farther than T3 from the firing positions. In T3, lead, chromium and zinc concentrations were 2,630, 278 and 1,520 ppm respectively, four times the ISQGL threshold values. Finally, Cr (278 ppm in T3), Cu (587 ppm in T1 and 5,530 ppm in T3), Mo (41 ppm in T3), Ni (177 in T3) and Cd (5.4 ppm in T3) concentrations were higher than the ISQGL.

For the energetic materials, all samples at the target positions showed HMX concentrations ranging from 6.75 to 1,339.2 ppm, the T3 samples being the most contaminated. All these samples also contained nitroglycerine that is the result of incomplete combustion of the propellant before hitting the target, breaking into pieces and spreading the content of the shells on the ground. Nitroglycerine concentrations varied from 1.94 to 382.8 ppm, the T3 samples being the most contaminated.

All the firing position samples showed nitroglycerine at concentrations varying from 108.9 to 3,974.4 ppm. Behind the firing positions contamination was similar, the B position being slightly more contaminated. It was observed in Table 7 that, the concentrations of nitroglycerine are very high up to 2,000-3,000 ppm from 0-15m then, the concentrations are decreasing at 15-25 m to 100-300 ppm. This situation is identical to other anti-tank ranges and is typical of the contamination observed with those weapons (Ref. 48). This range was the last where metal analyses were performed. All the following ranges did not have any metal analyses performed for their soil samples.

4.10 Dieppe Range

As already mentioned in section 4.2, Dieppe, Cambrai and Caen ranges are very similar and served as firing positions for many types of weapons such as: 105 mm Leopard tank, LAV Cougar 76 mm, Grizzly for 25 mm medium calibre, 105 mm Howitzer artillery gun, mortars, etc. Machine guns are also used on this site and wooden positions were found in front of the concrete pad. The large concrete pad is used for most of the firings. Excess artillery bags were burned on the pad in May 2007 and a sample was collected and named M-07- Dieppe-PAD. The Dieppe site is located on the left side of the observation tower (Fig 4).

For energetic materials in Dieppe, the concrete pad was measured and its 45-m width was divided into three sections of 15 m. A composite sample was built in front of the concrete pad in front of the specific 15 m wide area with a depth of 10 m. These 10 x 15 m areas were named M-07-Dieppe-1, 2 and 3 from left to right (Fig. 22). Duplicate composite samples were also collected around machine gun positions and were named M-07-DIEPPE-4 and 4-Dup. If one examines Tables 7 and 8, it is observed that all samples showed propellant residues but no explosives except the duplicate sample in position 4 that showed RDX at 0.25 ppm. This last result is probably an anomaly and should not be considered. Nitroglycerine was detected at low concentrations of 0.78 to 16.39 ppm in all samples. 2,4-DNT was also observed at low concentrations of 0.11-2.33 ppm.

The higher concentration of 2,4-DNT was found on the pad and this is normal since this is the result of the open burning combustion of M1 propellant. Otherwise, all the DNT concentrations are very low and of no concern. Nitroglycerine concentrations are also very low and do not represent a problem. No action is required on this site.

4.11 Caen Range

As already mentioned in section 4.2, Caen is the third of the series of ranges that served as firing positions for many types of weapons such as: 105 mm Leopard tank, LAV Cougar 76 mm, Grizzly for 25 mm medium calibre, 105 mm Howitzer artillery gun, mortars etc. It has a large, 90 m wide concrete pad. The Caen site is located on the right side of the observation tower (Fig 4).

For energetic materials in Caen, the concrete pad was measured and its 90 m width was divided into six sections of 15 m. Composite samples were built in front of the concrete pad in front of the specific 15 m wide areas with a depth of 10 m and were named M-07-Caen-1, 2, 3,… and 6 from left to right (Fig. 23). If one examines Tables 7 and 8, it is observed that all samples showed propellant residues but no explosives. Nitroglycerine was detected in all samples at higher concentrations than in Dieppe varying from 3.32 to 67.24 ppm. There was no specific pattern of deposition along the pad indicating that its entire width was used for the firings. 2,4-DNT was also observed at higher concentrations than in Dieppe with concentrations varying from 6.84 to 47.96 ppm. For the first time, some 2,6-DNT was detected in some of these samples at concentrations varying from 0.76 to 1.70 ppm. 2,6-DNT is an impurity of the 2,4-DNT and can be found at 30% concentration in commercial 2,4-DNT (Ref. 45). This proportion was not observed in these soil samples.

These higher concentrations of nitroglycerine and 2,4-DNT compared to Dieppe Range indicate that there are more artillery firings on this range. Nevertheless, all the nitroglycerine and DNT concentrations are very low and of no concern at this moment and do not represent a problem. No action is required on this site.

4.12 Cassino Range

This range is quite new and is used to practice 40 mm grenade launches (Figs. 24-25). The 40 mm are supposed to be of the self-destruct type. No sampling was done in the 40 mm impact area. Duplicate composite samples were built around the firing positions and revealed no energetic materials. This site is not contaminated by explosives. The impact area for 40 mm should be screened for explosives during the next sampling in August 2008.

4.13 Special Unit

This range is used for shooting 40 mm grenades using the MK19 launchers. The impact zone was too dangerous to be sampled since it was highly vegetated. For this reason it was decided to sample the firing positions of the range that were close to the road located at 0525404 northern and 4947606 western. There was a wooden pad that served as the firing position but shooting could be conducted from beside that pad anywhere on a 60-m width. According to Figure 26, the pad was placed at 10 m from the left hand edge of the 60-m width. Four soil samples were collected and were composited using 50 sub-samples, one for the left 30-m area named M-07-US-1 and the other for the right 30-m area named M-07-US-2. Duplicate samples were collected for both areas and revealed no energetic materials on those firing positions (Table 7). No action is required at this site.

4.14 Messines Range

This range is a demolition range and is equipped with a bunker and an area where wiring the explosives to the bunker can be easily accomplished (Fig. 27). On this site, steel cutting is performed on a small berm to the right (Fig. 28). Normally in demolition ranges, the engineers practice steel cutting, wood cutting, concrete cutting and sometimes cratering. Usually, these types of ranges are contaminated by explosives at high levels since demolition using unconfined C-4 may spread RDX, especially when low order detonations are obtained. We were told that the site was used 4-5 times a year and we foresaw low levels of explosive contamination.

Composite soil samples were collected in the three areas of the site, one on the berm on the right and the two others in the middle of what seemed to be the locations of previous detonations (Fig.28). We collected a duplicate sample for area 2 since it seems to be more used than the others. In Table 8, it is seen that HMX and RDX are found at quite high levels. HMX is an impurity of the Bachmann production process of RDX and therefore, RDX may contain up to 10-15% of HMX. In open detonation occurring from blow in place operations such as in the demolition range, it is usual that low order detonations happen from time to time. This results in the spreading of RDX but also of HMX and if one looks carefully at the HMX concentrations versus RDX concentrations, it can be seen that the HMX is present at almost 10% of RDX in all cases. This indicates that HMX is likely coming from RDX as an impurity rather than from a bad detonation of an item that contained HMX such as shoulder type weapons that contains octol, a mixture of TNT:HMX 25:75. Sometimes, live ammunition is brought to demolition ranges to be exploded to practice blow in place procedures. Most of the time, these ammunitions contain TNT and this is why TNT is often observed in demo ranges. TNT can also come from a cratering practice that uses TNT ammunition.

Area 3 seems to be the least used, being the farthest from the bunker and the closest to the exit. Only RDX was detected at low concentrations of 0.28 and 0.32 ppm. Area 1 is the most contaminated and contained HMX, RDX and TNT. In this area, steel cutting practices are performed and RDX was found at concentrations of 34.28 to 42.04 ppm. HMX was found at 3.00 to 3.68 ppm almost 10% of the RDX concentration. TNT was also observed at concentrations of 3.6 to 4.16 ppm.

Area 2 concentrations are lower than area 1 but the same contaminants are observed. It is surprising that the Dup sample showed more significant concentrations of RDX and HMX compared to sample M-07-Mes-OD-2, its counterpart. It is likely that we collected a chunk of RDX during that sampling, introducing an increase of RDX and HMX as well, showing how heterogeneous it can be. This is confirmed by the fact that both area 2 samples contain approximately the same concentrations of TNT. RDX was found in this area at levels of 9.19 to 80.78 ppm in the dup sample. HMX is also observed at 0.80 to 6.04 ppm, the proportion HMX/RDX being again close to 10%. TNT was found at concentrations of 0.88-1.76 ppm. It is interesting to note that TNT metabolites are seen for the first time in this study. 2-ADNT and 4-ADNT were observed in both areas 1 and 2 at low concentrations of 0.17 to 0.79 ppm. Nitroglycerine and 2,4-DNT were observed in areas 1 and 2 and are probably coming from open burning to practice propellant burning such as obsolete double base or M1 propellants. Nitroglycerine was found at concentrations of 2.73 to 4.88 ppm in area 1 only while 2,4-DNT was found at concentrations of 0.20 to 0.64 ppm in both areas 1 and 2. In general, this site showed low contamination, so no action is required for this moment.

4.15 Normandy Range

This range is used for mortar firings mainly 66 mm mortars. On the range, there were four firing positions where mortars were installed. In front of the firing positions, there was a berm 1 km away and this berm was not sampled. Normally, trainers installed the launcher behind the wooden wall and fired from there (Fig. 29). Soil composite samples were collected behind these wood structures for each of the firing positions and were named M-07-NORM-1, 2, 3 and 4. A duplicate was collected for position 4 and was named M-07-NORM-4-Dup. Furthermore, to evaluate if residues were ejected in front of the positions, a composite sample was collected in front of firing position 4 and was named M-07-NORM-4 avant which means in front of (Fig. 30). Nitroglycerine was found only in positions 2-4 and concentrations were low ranging from 0.18-0.72 ppm. 2,4-DNT was found only in position 2 at 0.07 and 0.08 ppm. The Dup sample showed no energetic materials and the samples in position 1 and in front of position 4 showed no contamination. An isolated hit of HMX was found in position 4. These low concentrations do not represent a problem. No action is required.

4.16 Road Crossing Firing Position

During our first visit in April 2007, we stopped at a firing position named position 408 where 105 mm artillery guns and 81 mm mortars were fired (Fig 31). Just after this position on the road, there was a four roads junction that we named 408 road crossing. This junction of roads was used as firing positions for 105 mm artillery guns firing at the impact area (Fig. 32). Composite soil samples were collected to evaluate this position. Two composite samples were built and named M-07-RC-1 and 2. No energetic materials were found at this location. In August 2008, we will go back to position 408 and sample this location again.

4.17 Pusan Range

This range was similar to Caen, Cambrai and Dieppe but was not located close to the observation tower. It served as firing positions for many types of weapons but mainly for 105 mm firings. The large concrete pad is used for most of the firings (Fig. 33). Excess artillery bags were probably burned on the pad from time to time but we saw no impact on the pad. No sample was collected on the pad. It was decided not to sample this range since it was very similar to the others (Caen, etc.) and furthermore, the site was much vegetated making the sampling extremely difficult. In front of the middle of the concrete pad, there was an area where there was no vegetation. A single sample was collected in this area and was named M-07-PUSAN.

Only nitroglycerine and DNTs were found in the sample from this range. NG was found at 6.65 and 7.07 ppm while 2,4-DNT was found at 4.62 and 5.31 ppm. 2,6-DNT was also detected at concentrations of 0.2 ppm. These concentrations are very low, of no concern and do not represent a problem. No action is required on this site.

4.18 Global Results in all Ranges

Generally, the levels of metals in soils in all of the ranges were quite low. Most of the metal exceedances were close to the BGL concentrations. Furthermore, concentrations were typically far below the ASQG or the ISQG. Some metals that were systematically present at high concentrations, such as lead, chromium, copper, antimony, arsenic, zinc, and cadmium can be related to firing activities. Selenium was found around tank targets at high concentrations in Cambrai and this will be investigated further. The fact that metals concentrations were low in the ranges is the direct result of good management of the sites performed by range control and the low use of this training area compared to other highly used Canadian Forces Bases. During the visit in September 2007, the sites were clear of debris and of large pieces of metal. In general, the removal of metals, when performed on a regular basis represents the best practice to keep metal concentrations low and makes a significant contribution to environmental stewardship.

The energetic materials analyses revealed that there are no major impacts related to the activities at this training area. Some hot spots were found but their concentrations are lower than what is usually found in other similar training areas. In general, the soils are of excellent quality. No action is required on any sites except to continue to clean and manage the sites as is currently done. Metal concentrations in the small arms ranges are to be monitored every two-three year to evaluate if the concentrations are increasing. Although, most of them did not exceed the ISQG criteria, many of the results are higher than the ASQG. As already mentioned, legally, no action is required, since the site will not be used for agriculture, but will continue to be used for target practice. The most important results will come from the hydrogeological study.

5 Conclusion

In September 2007, DRDC Valcartier and INRS conducted for Director Land Environment (DLE) the first phase to characterize the soil, surface water and groundwater for metals and energetic materials at Land Force Central Area Training Centre (LFCATC) Meaford, Ontario. The Institut national de la recherche scientifique (INRS) was responsible for sampling the surface water and groundwater for metals and explosives and produced a separate report describing their results. In our study, most of the ranges of the LFCA TC Meaford were sampled during the September 2007 campaign. A total of 17 ranges were sampled to evaluate the explosives and/or metals contamination. More precisely, at the small arms ranges, skeet range, artillery firing positions, anti-tank, grenade and other ranges, 135 soil samples were collected including 79 for energetic materials, 56 for metals and seven for polycyclic aromatic hydrocarbons (PAHs) analyses. Water samples (35) were collected by INRS, analysed by DRDC Valcartier and revealed no energetic materials. 20 background samples were taken for the metals evaluation and served as comparison. Metals were analysed in Apeldorn grenade range, Cambrai, Ortona, Urban Assault, Paardeburg antitank, and in all the small arms ranges Gully, Alpha, Gravenstafel Ridge and Skeet ranges. Metal analyses were done using Inductively Coupled Plasma /Mass Spectrometry (ICP/MS) and explosives concentrations were determined using the High Pressure Liquid Chromatography (HPLC) Method EPA 8330b.

Many different sampling strategies were used to collect samples across the ranges and were explained in detail in section 4. A linear sampling pattern was used at the Apeldorn grenade and Paadeburg anti-tank ranges and also in front of the firing positions of the Alpha small arms range. This approach was used to evaluate whether the level of contamination by explosives and/or by metals was following a pattern with distance from the firing positions. The concentrations were also evaluated behind and in front of the targets at several ranges, such as the tank targets at Cambrai, the targets at Paardeburg and also in front of the firing lines at the small arms ranges.

Generally, results from Phase I showed that the concentrations of metals in soils in all of the ranges were quite low. Most of the time, the metals detected at concentrations higher than the BGL were far below the ASQG or the ISQGL except for some metals such as lead, chromium, copper, antimony, arsenic, zinc, and cadmium, which were present at higher concentrations. These metals can be related to firing activities. Selenium was found at high concentrations around tank targets at Cambrai and this will be investigated further. The fact that metals concentrations were generally low in the ranges is the direct result of good management of the sites performed by range control and the low use of this training area compared to other highly used Canadian Forces Bases. During the visit in September 2007, the sites were clear of debris and of large pieces of metal. In general, the removal of metals, when performed on a regular basis represents the best practice to keep metal concentrations low and makes a significant contribution to environmental stewardship.

The energetic materials analyses revealed that there are no major impacts related to the activities at this training area. Some hot spots were found but their concentrations were lower than what is usually found in other similar training areas. Good examples of this are the targets in the Paardeburg anti-tank range that are contaminated by HMX at concentrations of 1,300 ppm while other anti-tank ranges at other bases showed HMX concentrations up to 7,000 ppm. The same situation is encountered with small arms ranges where maximum lead concentrations were found in Alpha at 6,000 ppm while in other typical small arms ranges, lead concentrations reached 70,000 ppm.

In general, the soils are of excellent quality. No action is required on any sites except to continue to clean and manage the sites as is currently done. Metal concentrations in the small arms ranges are to be monitored from time to time. Although, most of them did not exceed the ISQG criteria, many of the results are higher than the ASQG. As already mentioned, legally, no action is required, since the site will not be used for agriculture, but will continue to be used for target practice. The most important results will come from the hydrogeological study.

In conclusion, this study demonstrated that the ranges have some accumulation of metals due to firing activities, but the extent of contamination is very low. Contamination by explosives is also minimal except around targets in the Paardeburg Anti-tank range. The firing positions are also quite clean compared to other bases where levels as high as 20,000 ppm were observed for nitroglycerine compared to 4,000 ppm in the firing positions of the Paardeburg anti-tank range.

For Phase II of this study which will be conducted in August 2008, many sites will be revisited to better define the pattern of contamination. The Apeldorn grenade, the tanks in Cambrai, the Urban Assault, Caen, Cassino and Normandy ranges will need more sampling to finalize the understanding of the contamination. Furthermore, Position 408, the stop berm in the impact zone and the gravel pit will be evaluated since it was not possible to sample these sites during Phase I of the study.

6 Figures

Figure 1: The Bunker in Apeldorn Grenade Range

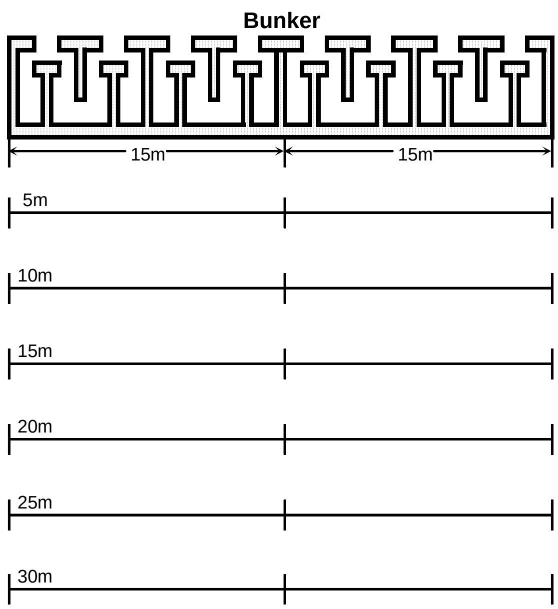

Figure 2: Sampling Strategy in Apeldorn Grenade Range.

Figure 3: View from Dieppe of the Impact Area Stop Butt.

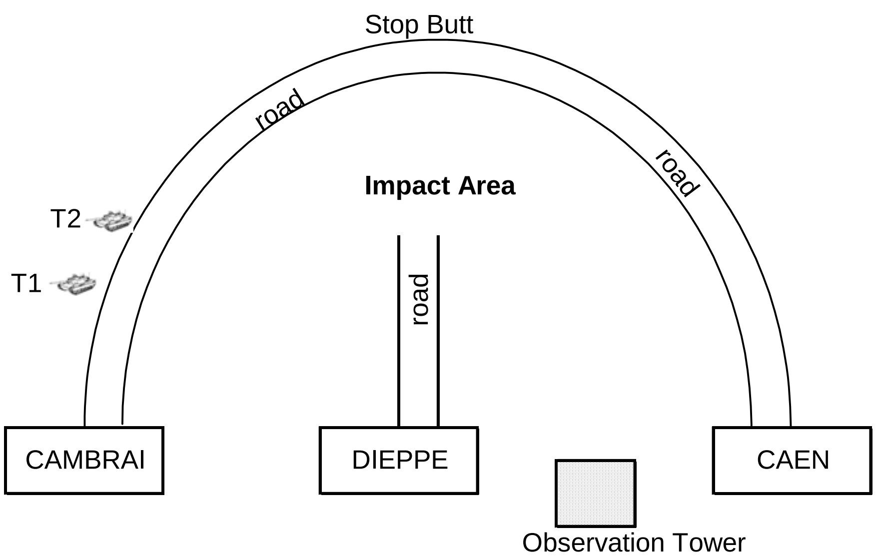

Figure 4: Locations of Ranges around the Observation Tower.

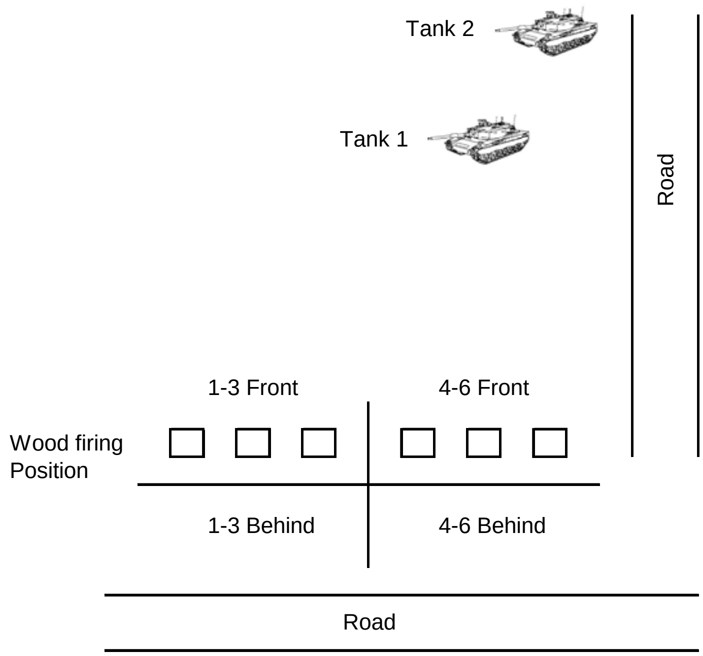

Figure 5: Sampling Strategy in Cambrai Range

Figure 6: Sampling House no 1 in Ortona FIBUA Site

Figure 7: Sampling House no 2 in Ortona FIBUA Site.

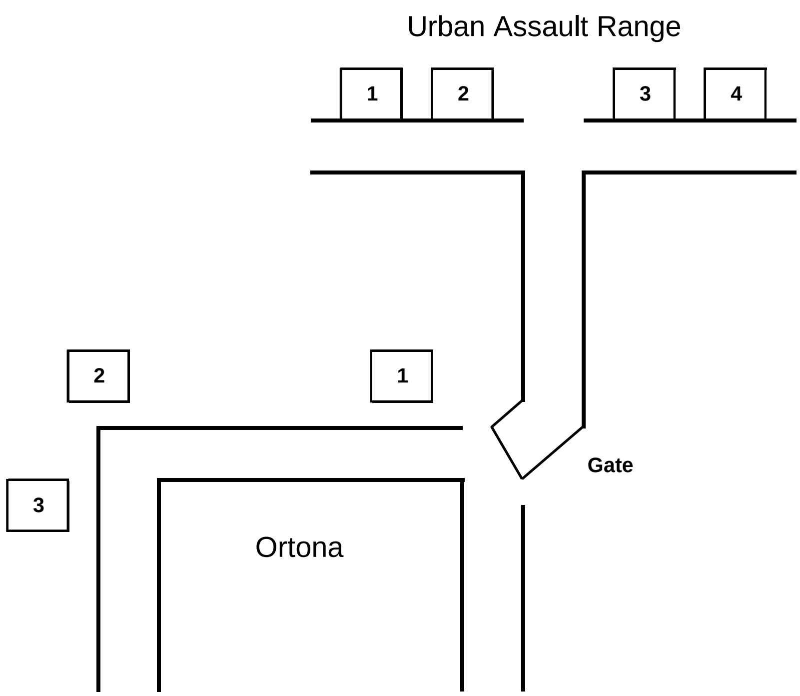

Figure 8: Sampling Strategy in Ortona and Urban Assault Ranges

Figure 9: Structures Mimicking Houses in Urban Assault Range

Figure 10: Rail System for Moving Targets in Urban Assault Range

Figure 11: Gravenstafel Ridge Target Positions in April 2007.

Figure 12: Gravenstafel Ridge Small Arms Range in September 2007.

Figure 13: Gully Small Arms Range.

Figure 14: Alpha Small Arms Range.

Figure 15: Sampling of Firing Positions in Alpha Small Arms Range

Figure 16: Impact Area of the Skeet Range

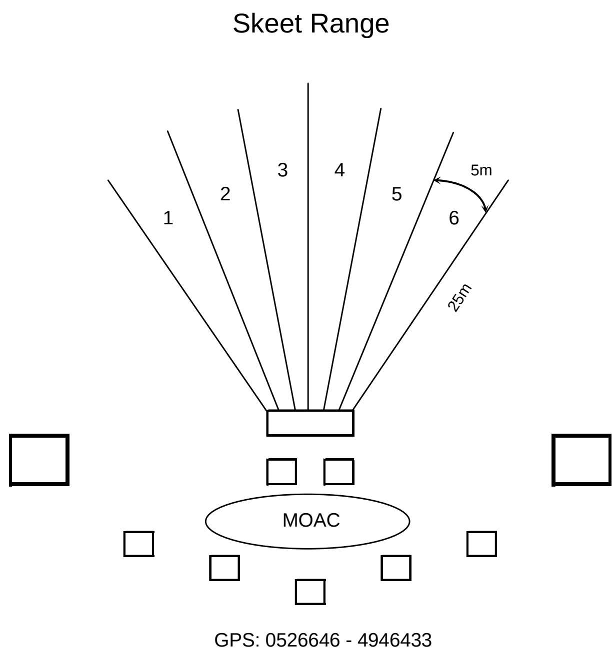

Figure 17: Sampling Strategy used for the Skeet Range Characterization

Figure 18: View of the Skeet Range Firing Positions.

Figure 19: Firing Positions of the Paardeburg Anti-Tank Range.

Figure 20: Targets in the Paardeburg Anti-Tank Range

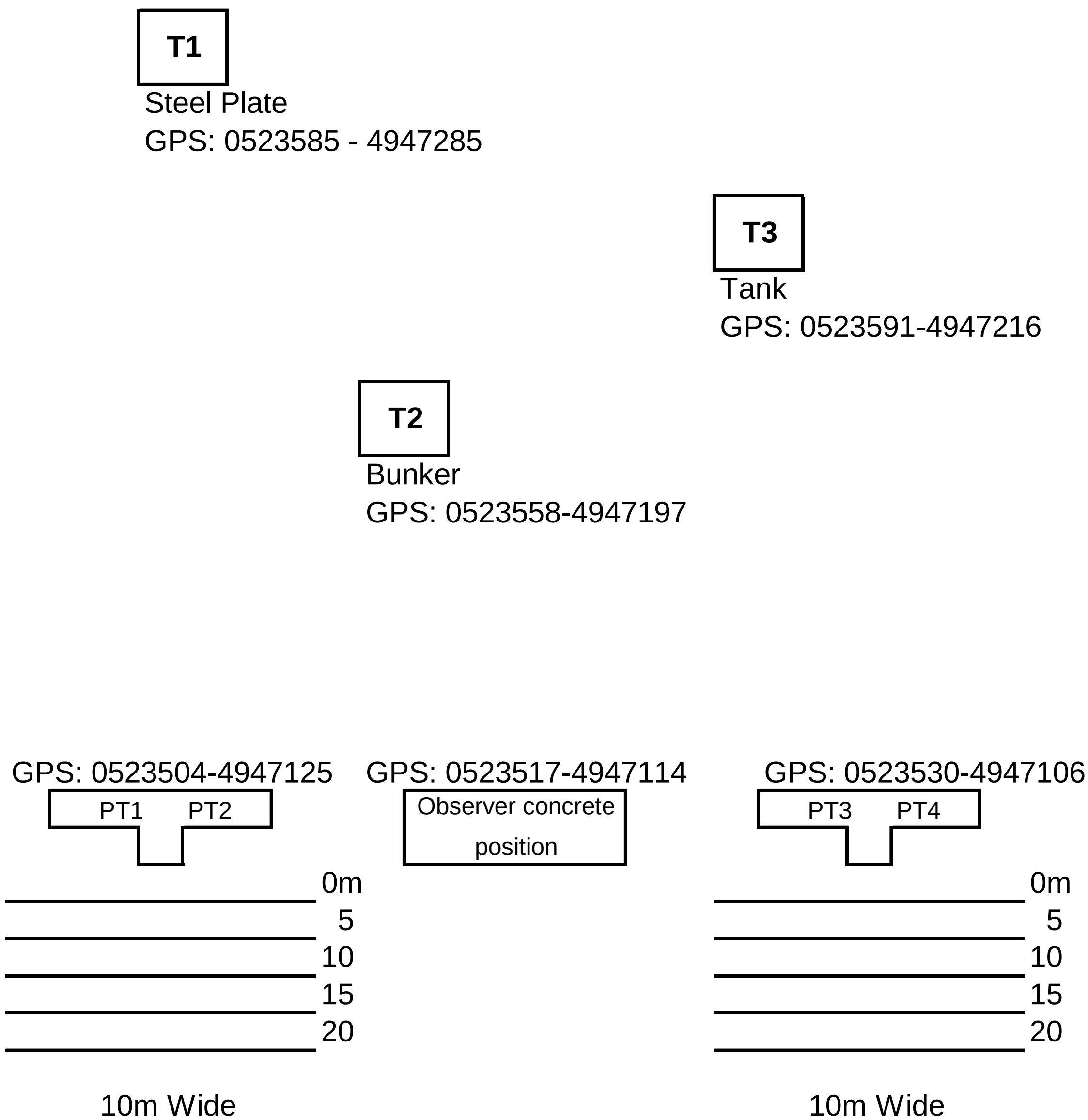

Figure 21: Sampling Strategy for the Paardeburg Anti-Tank Range

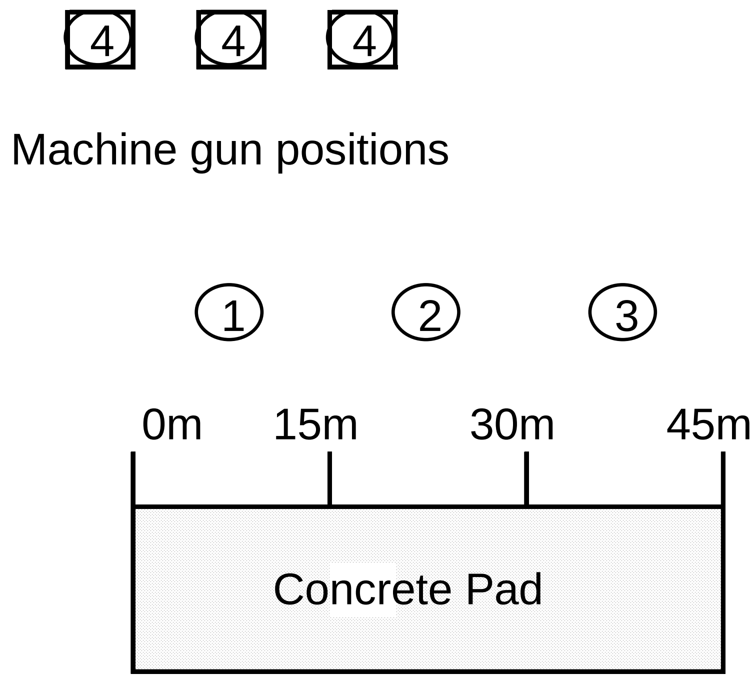

Figure 22: Sampling Strategy in Dieppe Range

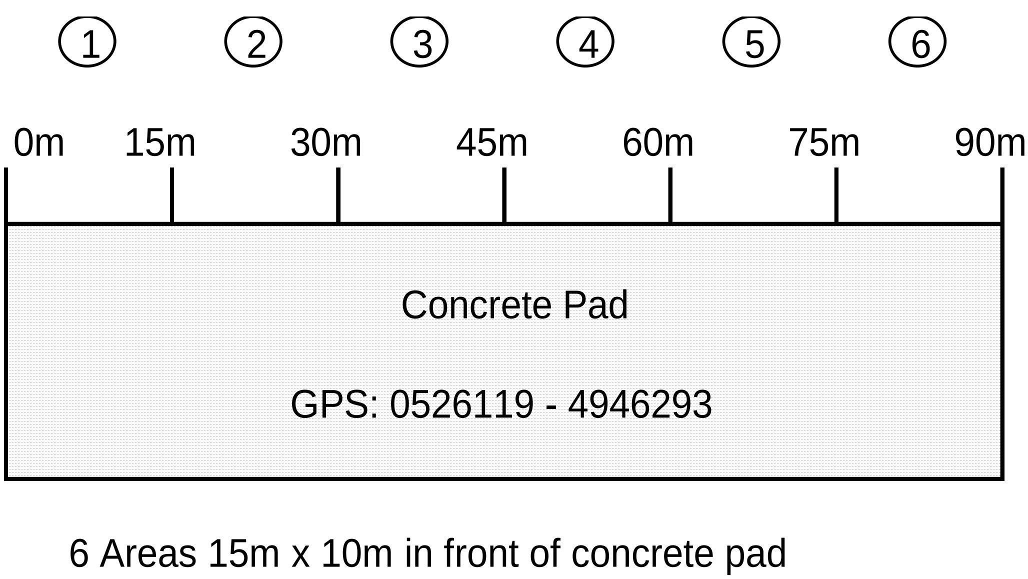

Figure 23: Sampling Strategy in Caen Range

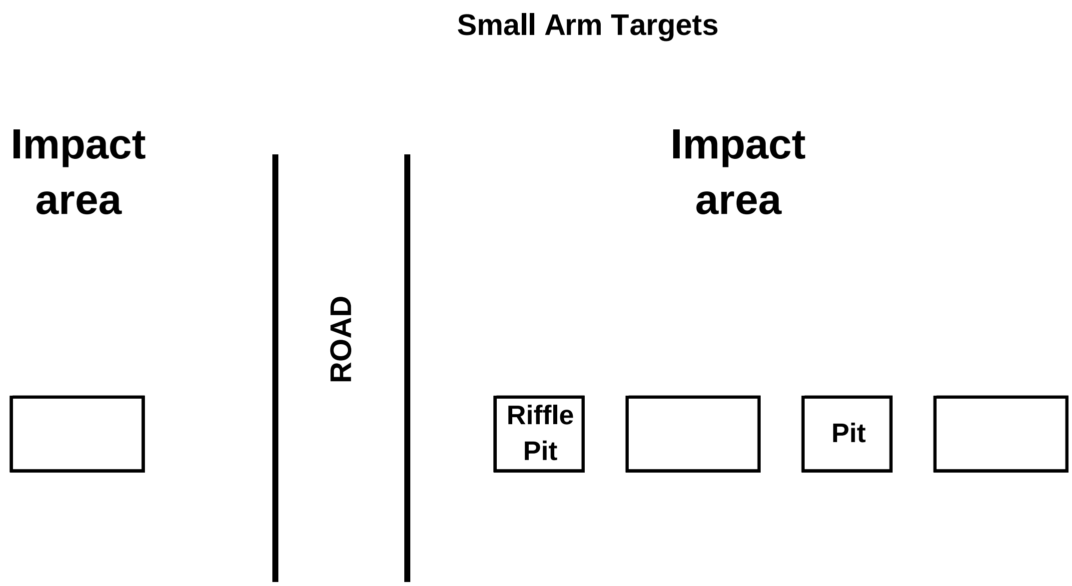

Figure 24: Sampling Strategy in Cassino Range

Figure 25: Firing Positions in Cassino Range

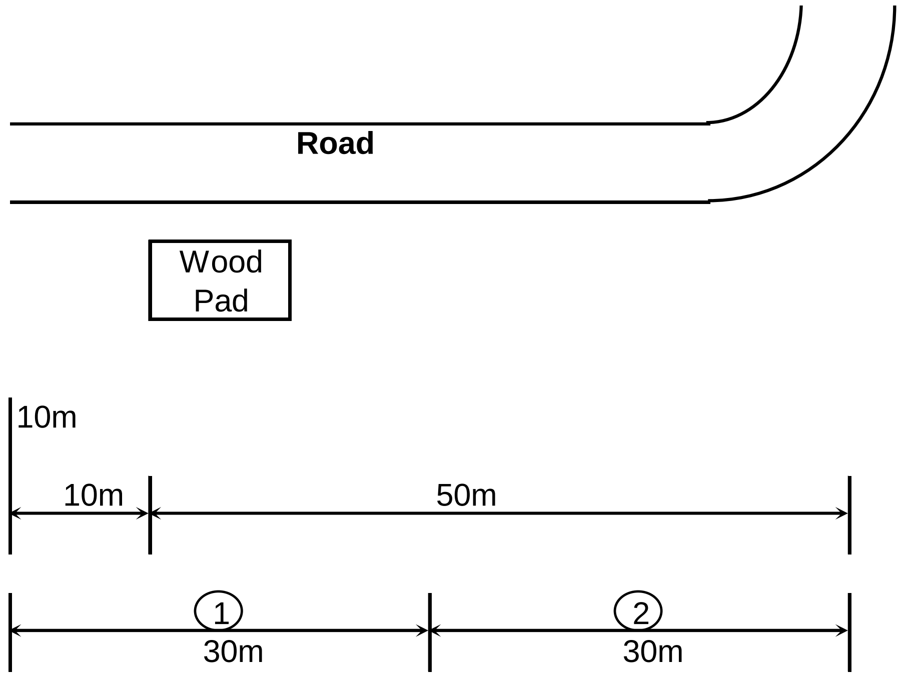

Figure 26: Sampling Strategy in Special Unit Range.

Figure 27: Bunker in Messines Demolition Range.

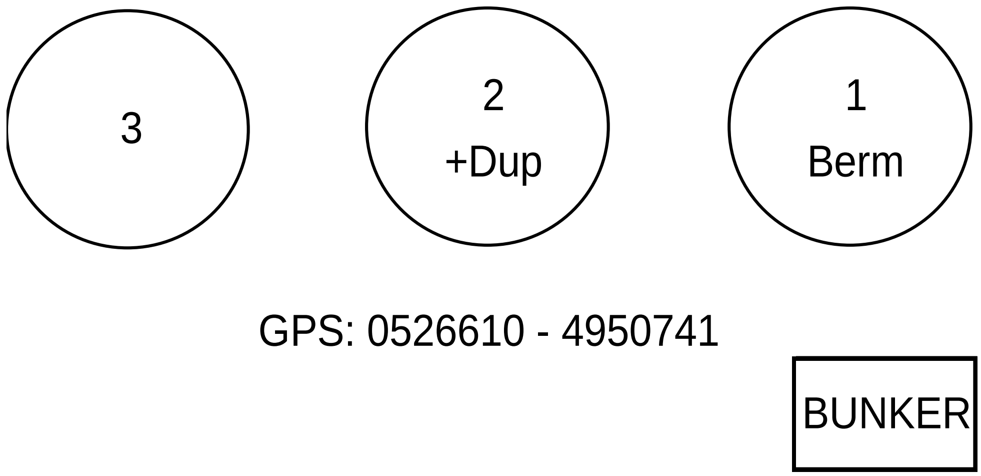

Figure 28: Sampling Strategy in Messines Demolition Range

Figure 29: Mortar Firing Positions in Normandy Range

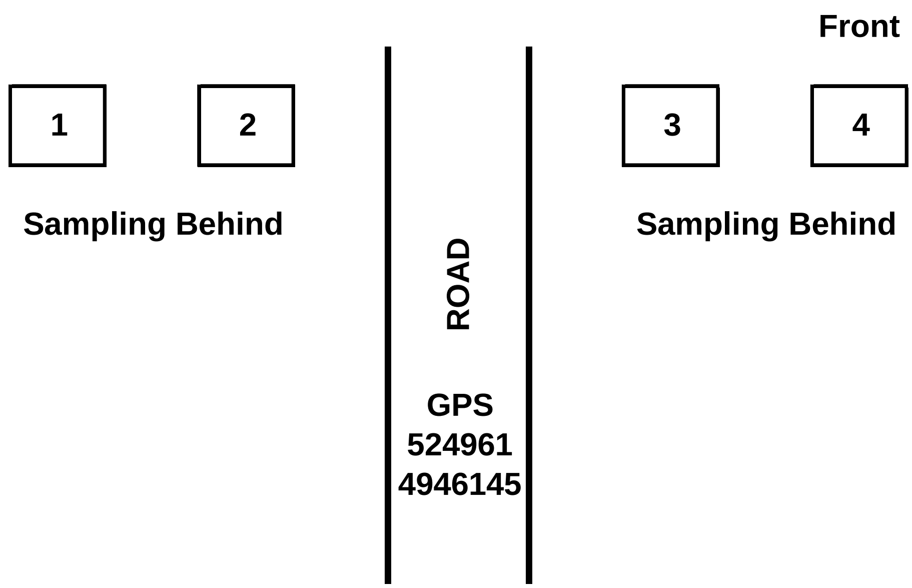

Figure 30: Sampling Strategy in Normandy Range

Figure 31: Artillery Firing Positions at Position 408

Figure 32: Artillery Firing Positions at Road Crossing.

Figure 33: Concrete pad in Pusan Range

7 Tables

Table 1: GPS LOCATIONS OF SAMPLING.

Sampling Locations or Sample ID	Sampling Point	
	X or Northern	Y or Western
BACKGROUND SAMPLES		
M-07-BG-1	0525601	4945850
M-07-BG-2	0527214	4946032
M-07-BG-3 and M-07-BG-4 (same locations)	0528126	4946463
M-07-BG-5	0528753	4946398
M-07-BG-6	0528783	4947485
M-07-BG-7	0528723	4947929
M-07-BG-8	0528630	4948486
M-07-BG-9	0528524	4949159
M-07-BG-10	0528437	4949676
M-07-BG-11	0528239	4950822
M-07-BG-12	0527515	4951098
M-07-BG-13	0526238	4950895
M-07-BG-14	0527073	4952099
M-07-BG-15	0524781	4951520
M-07-BG-16	0521314	4949873
M-07-BG-17	05220211	4948596
M-07-BG-18	0520564	4946535
M-07-BG-19	05221689	4945465
M-07-BG-20	05236350	4945902
SPECIAL UNIT RANGE		
Firing position	0525404	4947606
NORMANDY		
Firing position	0524961	4946145
408 ROAD CROSSING		
Firing position	0523412	4945986

Sampling Locations or Sample ID	Sampling Point	
	X or Northern	Y or Western
CAMBRAI		
Firing position	0525824	4946012
Tank 1	05258824	4946308
Tank 2	0525757	4946423
CAEN		
Firing position concrete pad	0526119	4946293
DIEPPE		
Firing position in front of concrete pad	0526003	4946093
PAARDEBURG ANTI-TANK		
Firing position left of observatory	0523504	4947125
Observatory	0523517	4947114
Firing positions right of observatory	0523530	4947106
Tank 1	0523585	4947285
Tank 2	0523558	4947197
Tank 3	05223591	4947216
FIBUA ON ORTONA		
Front door of first building	0522372	4946114
URBAN ASSAULT RANGE NORTHEAST OF ORTONA		
Target right of the road	0522461	4946817
PUSAN		
In front of the concrete pad	0526359	4946480
SKEET RANGE		
Behind the staircase	0526646	4946433
ALPHA SMALL ARMS RANGE		
In front of the target	0526919	4946600
GRAVENSTAFEL RIDGE		
In front of the target	0528670	4947490
APELDORN GRENADE RANGE		
Beside the bunker	0527290	4951133
MESSINES		
Middle of the site	0526610	4950741

Table 2: METALS CONCENTRATIONS IN SOILS (Al to B)

	Al	Sb	As	Ba	Be	Bi	B
Sample			**ppm**	**(mg/kg)**			
BACKGROUND							
M-07-BG-1	7070	0.4	3	24	0.4	4	0.21
M-07-BG-2	10700	0.4	11	94	0.8	4	0.20
M-07-BG-3	9620	0.4	3	36	0.7	4	0.42
M-07-BG-4	10400	0.4	3	38	0.6	4	0.41
M-07-BG-5	3620	0.4	4	25	0.4	4	0.19
M-07-BG-6	14000	0.4	6	69	0.7	4	0.47
M-07-BG-7	3650	0.4	4	27	0.4	4	0.23
M-07-BG-8	3720	0.4	4	31	0.4	4	0.53
M-07-BG-9	9930	0.4	4	43	0.6	4	0.92
M-07-BG-10	6860	0.4	4	26	0.4	4	0.66
M-07-BG-11	5500	0.4	9	62	0.4	4	0.51
M-07-BG-12	8030	0.4	5	48	0.5	4	0.92
M-07-BG-13	3280	0.4	4	32	0.4	4	0.20
M-07-BG-14	3720	0.4	5	39	0.4	4	0.19
M-07-BG-15	4780	0.4	4	34	0.4	4	0.30
M-07-BG-16	9740	0.4	11	42	0.8	4	0.22
M-07-BG-17	9550	0.4	4	40	0.6	4	0.35
M-07-BG-18	9570	0.4	4	40	0.6	4	0.49
M-07-BG-19	4450	0.4	4	27	0.4	4	0.62
M-07-BG-20	10700	0.4	2	16	0.7	4	0.03
Average	7445	0.4	5	40	0.5	4	0.40
Standard deviation	3186	0.0	3	18	0.1	0	0.24
(2 x St Dev))	6371	0.0	5	36	0.3	0	0.48
Sum (Ave+(2xStDev)	13816	0.4	10	76	0.8	4	0.89
CCME ASQG (a)		20	12	750	4		2
CCME ISQG (b)		40	12	2000	8		
APELDORN GRENADE RANGE							
M-07-AGR-0-5 M	1860	0.4	3	46	0.4	4	0.04
M-07-AGR-5-10 M	1770	0.4	2	71	0.4	4	0.07
M-07-AGR-10-15 M	2180	0.4	2	**105**	0.4	4	0.04
M-07-AGR-10-15 M Dup	2010	0.4	2	**81**	0.4	4	0.05

	Al	Sb	As	Ba	Be	Bi	B
Sample			**ppm**	**(mg/kg)**			
M-07-AGR-15-20 M	2030	0.4	2	**87**	0.4	4	0.03
M-07-AGR-20-25 M	1980	0.4	2	64	0.4	4	0.04
M-07-AGR-25-30 M	1980	0.4	3	48	0.4	4	0.05
CAMBRAI							
M-07-CAM-T1	1320	0.4	**38**	**186**	0.4	**27**	0.88
M-07-CAM-T2	956	0.4	**32**	**184**	0.4	**17**	**1.38**
FIBUA ON ORTONA							
M-07-FIBUA-1	3660	0.4	3	58	0.4	4	0.27
M-07-FIBUA-2	4010	0.4	5	41	0.4	4	0.46
M-07-FIBUA-3	5590	0.4	4	32	0.4	4	0.50
GRAVENSTAFEL RIDGE							
M-07-GSR-1-5	1380	**1.0**	2	10	0.4	4	0.19
M-07-GSR-6-10	1490	**1.9**	2	10	0.4	4	0.12
URBAN ASSAULT RANGE NORTHEAST OF ORTONA							
M-07-ORT-1	2690	**1.0**	3	18	0.4	4	0.05
M-07-ORT-2	6850	0.4	3	26	0.4	4	0.28
M-07-ORT-3	9660	0.4	3	38	0.5	4	0.71
M-07-ORT-4	2990	0.4	2	16	0.4	4	0.21
PAARDEBURG ANTI-TANK							
M-07-PAT-T1	9660	0.4	3	44	0.4	**28**	0.46
M-07-PAT-T3	**26900**	**2.7**	6	**304**	**1.1**	**90**	**1.18**
GULLY							
M-07-RG-1-6	1590	**20.2**	3	10	0.4	4	0.04
M-07-RG-7-12	1620	**15.1**	3	10	0.4	4	0.05
M-07-RG-13-18	1420	**16.6**	3	10	0.4	4	0.03
M-07-RG-19-24	1410	**5.2**	2	10	0.4	4	0.03
ALPHA SMALL ARMS RANGE							
M-07-SAR-1-6	1650	**69.6**	4	10	0.4	4	0.38
M-07-SAR-7-12	1550	**53.4**	4	10	0.4	4	0.14
M-07-SAR-13-18	1650	**41.9**	4	10	0.4	4	0.15
M-07-SAR-19-24	1590	**23.0**	2	10	0.4	4	0.12
M-07-SAR-25-30	1540	**3.9**	2	10	0.4	4	0.10
M-07-SAR-31-36	1570	**4.1**	2	10	0.4	4	0.04
SKEET RANGE							
M-07-SKEET-1	12600	0.4	6	49	0.7	4	0.38

Sample	Al	Sb	As	Ba	Be	Bi	B
	ppm (mg/kg)						
M-07-SKEET-2	10100	0.4	5	40	0.6	4	0.31
M-07-SKEET-3	8900	0.4	5	36	0.6	4	0.30
M-07-SKEET-4	8140	0.4	4	33	0.5	4	0.35
M-07-SKEET-5	6890	0.4	4	25	0.4	4	0.35
M-07-SKEET-6	7090	0.4	4	28	0.4	4	0.27

a: ASQG Agricultural Soil Quality Guideline

b: ISQG Industrial Soil Quality Guideline

Note: half values of the detection limits are used when metals are not detected

Values higher than the background mean + 2 x the standard deviation are highlighted in blue

Values higher than the CCME ASQG are highlighted in green

Values higher than the CCME ISQG are highlighted in red

Table 3: METALS CONCENTRATIONS IN SOILS (Cd to Fe)

	Cd	Ca	Cr	Co	Cu	Hg	Fe
Sample			**ppm**	**(mg/kg)**			
BACKGROUND							
M-07-BG-1	0.2	122000	13	9	15	0.05	19600
M-07-BG-2	0.5	24300	19	10	40	0.07	27200
M-07-BG-3	0.2	73000	15	12	42	0.05	20300
M-07-BG-4	0.2	81300	15	12	40	0.05	21400
M-07-BG-5	0.2	145000	6	5	25	0.05	15900
M-07-BG-6	0.4	33800	21	14	30	0.05	33600
M-07-BG-7	0.2	146000	6	5	29	0.05	17400
M-07-BG-8	0.2	162000	7	5	25	0.05	17900
M-07-BG-9	0.2	61500	16	8	23	0.05	23300
M-07-BG-10	0.2	85300	12	10	24	0.05	21000
M-07-BG-11	0.3	31000	7	6	19	0.05	27400
M-07-BG-12	0.3	39300	12	9	39	0.05	21500
M-07-BG-13	0.2	145000	6	5	29	0.05	17900
M-07-BG-14	0.2	133000	7	5	37	0.05	19300
M-07-BG-15	0.2	116000	8	6	34	0.05	20000
M-07-BG-16	0.2	31000	16	18	36	0.05	23400
M-07-BG-17	0.2	31400	16	10	23	0.05	21900
M-07-BG-18	0.2	49200	16	10	31	0.05	21200
M-07-BG-19	0.2	115000	8	6	18	0.05	15600
M-07-BG-20	0.2	128000	17	11	13	0.05	21900
Average	0.2	87655	12	9	29	0.05	21385
Standard deviation	0.1	47674	5	4	9	0.00	4243
(2 x St Dev))	0.2	95348	10	7	17	0.01	8485
Sum (Ave+(2xStDev)	0.4	183003	22	16	46	0.06	29870
CCME ASQG (a)	1.4		64	40	63	7	
CCME ISQG (b)	2.2		87	300	91	50	
APELDORN GRENADE RANGE							
M-07-AGR-0-5 M	0.2	145000	16	2	**48**	0.05	10500
M-07-AGR-5-10 M	0.2	143000	21	2	17	0.05	10600
M-07-AGR-10-15 M	0.2	160000	**26**	3	**64**	0.05	10700
M-07-AGR-10-15 M Dup	0.2	155000	20	2	22	0.05	10100

Sample	Cd	Ca	Cr	Co	Cu	Hg	Fe
	ppm (mg/kg)						
M-07-AGR-15-20 M	0.2	156000	21	3	20	0.05	10200
M-07-AGR-20-25 M	0.2	149000	18	2	14	0.05	8320
M-07-AGR-25-30 M	0.2	142000	15	2	13	0.05	8290
CAMBRAI							
M-07-CAM-T1	**3.9**	9020	**38**	1	**51**	**28.00**	179
M-07-CAM-T2	**3.0**	33200	**32**	1	39	**55.00**	86
FIBUA ON ORTONA							
M-07-FIBUA-1	0.2	115000	7	5	44	0.05	12800
M-07-FIBUA-2	0.2	131000	8	6	**54**	0.05	12300
M-07-FIBUA-3	0.2	81500	10	6	17	0.05	14200
GRAVENSTAFEL RIDGE							
M-07-GSR-1-5	0.2	124000	4	2	37	0.05	5540
M-07-GSR-6-10	0.2	125000	4	2	36	0.05	5560
URBAN ASSAULT RANGE NORTHEAST OF ORTONA							
M-07-ORT-1	0.3	76400	4	3	26	0.05	9470
M-07-ORT-2	0.2	23000	11	7	19	0.05	16700
M-07-ORT-3	0.2	45100	16	9	27	0.05	21900
M-07-ORT-4	0.2	84300	5	3	18	0.05	10400
PAARDEBURG ANTI-TANK							
M-07-PAT-T1	0.3	19600	**24**	7	**587**	0.05	17000
M-07-PAT-T3	**5.4**	38300	**278**	14	**5530**	**0.09**	**45500**
GULLY							
M-07-RG-1-6	0.2	131000	5	2	**202**	0.05	4650
M-07-RG-7-12	0.2	138000	5	2	**179**	0.05	4970
M-07-RG-13-18	0.2	130000	5	2	**264**	0.05	4530
M-07-RG-19-24	0.2	128000	5	2	33	0.05	4470
ALPHA SMALL ARMS RANGE							
M-07-SAR-1-6	0.2	124000	5	2	**207**	0.05	4780
M-07-SAR-7-12	0.2	125000	5	2	**227**	0.05	4510
M-07-SAR-13-18	0.2	130000	4	2	**132**	0.05	4610
M-07-SAR-19-24	0.2	128000	5	2	**165**	0.05	4540
M-07-SAR-25-30	0.2	127000	5	2	46	0.05	4330
M-07-SAR-31-36	0.2	128000	4	2	**68**	0.05	4350
SKEET RANGE							
M-07-SKEET-1	0.2	7640	16	11	30	0.05	25000

Sample	Cd	Ca	Cr	Co	Cu	Hg	Fe
	ppm (mg/kg)						
M-07-SKEET-2	0.2	30700	14	10	28	0.05	21500
M-07-SKEET-3	0.2	34000	13	9	25	0.05	19700
M-07-SKEET-4	0.2	52300	12	9	30	0.05	18400
M-07-SKEET-5	0.2	91000	11	8	23	0.05	15700
M-07-SKEET-6	0.2	95100	11	8	21	0.05	15600

a: ASQG Agricultural Soil Quality Guideline

b: ISQG Industrial Soil Quality Guideline

Note: half values of the detection limits are used when metals are not detected

Values higher than the background mean + 2 x the standard deviation are highlighted in blue

Values higher than the CCME ASQG are highlighted in green

Values higher than the CCME ISQG are highlighted in red

Table 4: METALS CONCENTRATIONS IN SOILS (Pb to K)

	Pb	Li	Mg	Mn	Mo	Ni	K
Sample			**ppm**	**(mg/kg)**			
BACKGROUND							
M-07-BG-1	10	21	21100	1160	1	20	1330
M-07-BG-2	19	10	12700	2610	1	16	744
M-07-BG-3	10	20	12900	1420	1	22	1940
M-07-BG-4	10	22	14100	1440	1	22	1810
M-07-BG-5	7	10	20200	1140	1	9	784
M-07-BG-6	15	31	9950	1240	1	28	2320
M-07-BG-7	7	10	15500	1210	1	9	638
M-07-BG-8	7	10	15700	1270	1	10	689
M-07-BG-9	17	14	6990	654	1	22	1210
M-07-BG-10	10	16	12000	866	1	20	1110
M-07-BG-11	21	11	4490	2180	1	10	764
M-07-BG-12	18	15	6350	1220	1	18	1630
M-07-BG-13	7	10	14400	1240	1	10	712
M-07-BG-14	8	10	12300	1310	1	12	765
M-07-BG-15	52	10	14200	1250	1	13	1040
M-07-BG-16	12	19	7380	1390	1	26	1890
M-07-BG-17	11	16	7230	839	1	19	1590
M-07-BG-18	11	17	8700	737	1	19	1850
M-07-BG-19	9	10	17500	1170	1	11	909
M-07-BG-20	4	32	27500	787	1	27	1780
Average	13	16	13060	1257	1	17	1275
Standard deviation	10	7	5680	458	0	6	530
(2 x St Dev))	20	14	11361	915	0	13	1061
Sum (Ave+(2xStDev)	34	29	24420	2172	1	30	2336
CCME ASQG (a)	70				5	50	
CCME ISQG (b)	600				40	50	
APELDORN GRENADE RANGE							
M-07-AGR-0-5 M	33	10	**34600**	392	1	26	366
M-07-AGR-5-10 M	**44**	10	**34800**	337	1	**34**	364
M-07-AGR-10-15 M	**67**	10	**44000**	373	1	**48**	375
M-07-AGR-10-15 M Dup	**58**	10	**38200**	346	1	**36**	415

Sample	Pb	Li	Mg	Mn	Mo	Ni	K
	ppm (mg/kg)						
M-07-AGR-15-20 M	**63**	10	**38300**	351	1	**39**	399
M-07-AGR-20-25 M	**44**	10	**40700**	311	1	**32**	303
M-07-AGR-25-30 M	**35**	10	**36400**	304	1	25	342
CAMBRAI							
M-07-CAM-T1	2	11	2320	186	**27**	1	4
M-07-CAM-T2	1	21	994	184	**17**	1	3
FIBUA ON ORTONA							
M-07-FIBUA-1	**40**	10	20600	884	1	10	608
M-07-FIBUA-2	10	10	**43400**	869	1	9	749
M-07-FIBUA-3	9	11	21400	737	1	11	1070
GRAVENSTAFEL RIDGE							
M-07-GSR-1-5	**230**	10	17500	327	1	6	292
M-07-GSR-6-10	**210**	10	17800	312	1	5	338
URBAN ASSAULT RANGE NORTHEAST OF ORTONA							
M-07-ORT-1	**735**	10	15000	581	1	6	396
M-07-ORT-2	**99**	14	5150	772	1	14	1020
M-07-ORT-3	**204**	22	11400	704	1	18	1480
M-07-ORT-4	**318**	10	16000	573	1	7	475
PAARDEBURG ANTI-TANK							
M-07-PAT-T1	**75**	12	6180	466	1	22	1180
M-07-PAT-T3	**2630**	11	10500	794	**41**	**177**	1030
GULLY							
M-07-RG-1-6	**4010**	10	**34200**	262	1	5	221
M-07-RG-7-12	**3470**	10	**34100**	291	1	5	240
M-07-RG-13-18	**3020**	10	**30100**	270	1	5	221
M-07-RG-19-24	**1220**	10	**32400**	253	1	5	234
ALPHA SMALL ARMS RANGE							
M-07-SAR-1-6	**6140**	10	**33500**	274	1	5	278
M-07-SAR-7-12	**5040**	10	**33700**	271	1	5	246
M-07-SAR-13-18	**4490**	10	**35800**	274	1	5	243
M-07-SAR-19-24	**2720**	10	**33100**	268	1	5	255
M-07-SAR-25-30	**1090**	10	**34500**	248	1	4	190
M-07-SAR-31-36	**932**	10	**36500**	255	1	4	176
SKEET RANGE							
M-07-SKEET-1	13	20	5870	888	1	22	1790

	Pb	Li	Mg	Mn	Mo	Ni	K
Sample	**ppm (mg/kg)**						
M-07-SKEET-2	14	18	7680	872	1	21	1500
M-07-SKEET-3	14	16	8080	840	1	19	1270
M-07-SKEET-4	13	16	11000	837	1	19	1190
M-07-SKEET-5	13	14	15000	749	1	17	1060
M-07-SKEET-6	13	15	16400	730	1	16	1050

a: ASQG Agricultural Soil Quality Guideline

b: ISQG Industrial Soil Quality Guideline

Note: half values of the detection limits are used when metals are not detected

Values higher than the background mean + 2 x the standard deviation are highlighted in blue

Values higher than the CCME ASQG are highlighted in green

Values higher than the CCME ISQG are highlighted in red

Table 5: METALS CONCENTRATIONS IN SOILS (Se to Ti)

	Se	Ag	Na	Sr	Sn	Tl	Ti
Sample			**ppm**	**(mg/kg)**			
BACKGROUND							
M-07-BG-1	2	0.2	107	119	4	0.1	15
M-07-BG-2	2	0.2	40	12	4	0.2	20
M-07-BG-3	2	0.2	76	78	4	0.1	68
M-07-BG-4	2	0.2	82	88	4	0.1	15
M-07-BG-5	2	0.2	93	130	4	0.1	19
M-07-BG-6	2	0.2	45	45	4	0.1	11
M-07-BG-7	2	0.2	79	138	4	0.1	18
M-07-BG-8	2	0.2	86	156	4	0.1	17
M-07-BG-9	2	0.2	72	85	4	0.1	20
M-07-BG-10	2	0.2	83	105	4	0.1	32
M-07-BG-11	2	0.2	40	38	4	0.1	15
M-07-BG-12	2	0.2	40	51	4	0.1	16
M-07-BG-13	2	0.2	84	142	4	0.1	63
M-07-BG-14	2	0.2	75	128	4	0.1	59
M-07-BG-15	2	0.2	75	118	4	0.1	17
M-07-BG-16	2	0.2	41	36	4	0.1	68
M-07-BG-17	2	0.2	40	37	4	0.1	95
M-07-BG-18	2	0.2	53	61	4	0.1	82
M-07-BG-19	2	0.2	81	104	4	0.1	41
M-07-BG-20	2	0.2	159	110	4	0.1	11
Average	2	0.2	73	89	4	0.1	35
Standard deviation	0	0.0	29	42	0	0.0	27
(2 x St Dev))	0	0.0	58	84	0	0.0	54
Sum (Ave+(2xStDev)	2	0.2	131	174	4	0.1	89
CCME ASQG (a)	1	20			5	1	
CCME ISQG (b)	3.9	40			300	1	
APELDORN GRENADE RANGE							
M-07-AGR-0-5 M	**2**	0.2	107	115	4	0.1	**110**
M-07-AGR-5-10 M	**2**	0.2	116	116	4	0.1	**115**
M-07-AGR-10-15 M	**2**	0.2	128	128	4	0.1	**104**
M-07-AGR-10-15 M Dup	**2**	0.2	130	125	4	0.1	**123**

Sample	Se	Ag	Na	Sr	Sn	Tl	Ti
	ppm (mg/kg)						
M-07-AGR-15-20 M	**2**	0.2	122	122	4	0.1	**115**
M-07-AGR-20-25 M	**2**	0.2	117	117	4	0.1	**100**
M-07-AGR-25-30 M	**2**	0.2	114	113	4	0.1	**166**
CAMBRAI							
M-07-CAM-T1	**9020**	**9.1**	49	**1320**	**51**	**0.9**	28
M-07-CAM-T2	**33200**	**5.2**	60	**956**	**39**	**0.5**	55
FIBUA ON ORTONA							
M-07-FIBUA-1	**2**	0.2	**389**	121	4	0.1	27
M-07-FIBUA-2	**2**	0.2	**258**	93	4	0.1	27
M-07-FIBUA-3	**2**	0.2	92	82	4	0.1	26
GRAVENSTAFEL RIDGE							
M-07-GSR-1-5	**2**	0.2	78	138	4	0.1	37
M-07-GSR-6-10	**2**	0.2	88	142	4	0.1	58
URBAN ASSAULT RANGE NORTHEAST OF ORTONA							
M-07-ORT-1	**2**	0.2	59	76	4	0.1	27
M-07-ORT-2	**2**	0.2	40	31	4	0.1	20
M-07-ORT-3	**2**	0.2	58	76	4	0.1	20
M-07-ORT-4	**2**	0.2	58	87	4	0.1	18
PAARDEBURG ANTI-TANK							
M-07-PAT-T1	**2**	**1.0**	58	31	4	0.1	33
M-07-PAT-T3	**2**	**15.7**	78	78	**6**	0.1	56
GULLY							
M-07-RG-1-6	**2**	0.2	104	122	**14**	0.1	87
M-07-RG-7-12	**2**	0.2	106	115	**12**	0.1	86
M-07-RG-13-18	**2**	0.2	95	111	**12**	0.1	79
M-07-RG-19-24	**2**	0.2	95	100	4	0.1	87
ALPHA SMALL ARMS RANGE							
M-07-SAR-1-6	**2**	**0.3**	102	97	**18**	0.1	**112**
M-07-SAR-7-12	**2**	**0.3**	102	99	**17**	0.1	**90**
M-07-SAR-13-18	**2**	0.2	108	105	**13**	0.1	**95**
M-07-SAR-19-24	**2**	0.2	108	108	**6**	0.1	**94**
M-07-SAR-25-30	**2**	0.2	101	106	4	0.1	76
M-07-SAR-31-36	**2**	0.2	103	105	4	0.1	77
SKEET RANGE							
M-07-SKEET-1	**2**	0.2	40	19	4	0.1	62

Sample	Se	Ag	Na	Sr	Sn	Tl	Ti
	ppm (mg/kg)						
M-07-SKEET-2	2	0.2	52	41	4	0.1	36
M-07-SKEET-3	2	0.2	52	45	4	0.1	37
M-07-SKEET-4	2	0.2	74	63	4	0.1	40
M-07-SKEET-5	2	0.2	83	101	4	0.1	33
M-07-SKEET-6	2	0.2	84	103	4	0.1	26

a: ASQG Agricultural Soil Quality Guideline

b: ISQG Industrial Soil Quality Guideline

Note: half values of the detection limits are used when metals are not detected

Values higher than the background mean + 2 x the standard deviation are highlighted in blue

Values higher than the CCME ASQG are highlighted in green

Values higher than the CCME ISQG are highlighted in red

Table 6: METALS CONCENTRATIONS IN SOILS (W to Zn)

	W	U	V	Zn
Sample	**ppm (mg/kg)**			
BACKGROUND				
M-07-BG-1	2	0.4	15	47
M-07-BG-2	2	1.3	23	53
M-07-BG-3	2	0.4	19	47
M-07-BG-4	2	0.4	17	49
M-07-BG-5	2	0.2	9	24
M-07-BG-6	2	0.5	23	86
M-07-BG-7	2	0.2	9	25
M-07-BG-8	2	0.2	9	22
M-07-BG-9	2	0.5	19	49
M-07-BG-10	2	0.4	14	55
M-07-BG-11	2	0.3	13	43
M-07-BG-12	2	0.3	15	57
M-07-BG-13	2	0.2	9	27
M-07-BG-14	2	0.2	11	31
M-07-BG-15	2	0.2	12	39
M-07-BG-16	2	0.3	20	50
M-07-BG-17	2	0.4	20	50
M-07-BG-18	2	0.3	20	53
M-07-BG-19	2	0.3	11	33
M-07-BG-20	2	0.4	15	48
Average	2	0.4	15	44
Standard deviation	0	0.2	5	15
(2 x St Dev))	0	0.5	9	30
Sum (Ave+(2xStDev)	2	0.9	25	74
CCME ASQG (a)			130	200
CCME ISQG (b)				360
APELDORN GRENADE RANGE				
M-07-AGR-0-5 M	2	0.3	7	**1570**
M-07-AGR-5-10 M	2	0.3	7	**1590**
M-07-AGR-10-15 M	2	0.3	8	**2140**
M-07-AGR-10-15 M Dup	2	0.3	7	**1780**

	W	U	V	Zn
Sample	**ppm (mg/kg)**			
M-07-AGR-15-20 M	2	0.3	8	**1690**
M-07-AGR-20-25 M	2	0.3	7	**1630**
M-07-AGR-25-30 M	2	0.3	9	**988**
CAMBRAI				
M-07-CAM-T1	**179**	**1.6**	11	**2320**
M-07-CAM-T2	**86**	**1.2**	21	**994**
FIBUA ON ORTONA				
M-07-FIBUA-1	2	0.3	9	**77**
M-07-FIBUA-2	2	0.4	10	66
M-07-FIBUA-3	2	0.4	13	63
GRAVENSTAFEL RIDGE				
M-07-GSR-1-5	2	0.2	4	14
M-07-GSR-6-10	2	0.2	5	12
URBAN ASSAULT RANGE NORTHEAST OF ORTONA				
M-07-ORT-1	2	0.2	6	17
M-07-ORT-2	2	0.4	14	35
M-07-ORT-3	2	0.7	18	49
M-07-ORT-4	2	0.3	7	16
PAARDEBURG ANTI-TANK				
M-07-PAT-T1	2	0.3	17	**236**
M-07-PAT-T3	2	0.5	23	**1520**
GULLY				
M-07-RG-1-6	2	0.3	6	33
M-07-RG-7-12	2	0.3	6	31
M-07-RG-13-18	2	0.3	6	36
M-07-RG-19-24	2	0.3	6	15
ALPHA SMALL ARMS RANGE				
M-07-SAR-1-6	2	0.3	7	33
M-07-SAR-7-12	2	0.3	6	33
M-07-SAR-13-18	2	0.3	6	28
M-07-SAR-19-24	2	0.3	6	28
M-07-SAR-25-30	2	0.3	6	16
M-07-SAR-31-36	2	0.2	6	19
SKEET RANGE				
M-07-SKEET-1	2	0.5	21	49

	W	U	V	Zn
Sample	ppm (mg/kg)			
M-07-SKEET-2	2	0.3	17	41
M-07-SKEET-3	2	0.4	16	38
M-07-SKEET-4	2	0.3	16	37
M-07-SKEET-5	2	0.3	13	32
M-07-SKEET-6	2	0.3	13	34

a: ASQG Agricultural Soil Quality Guideline

b: ISQG Industrial Soil Quality Guideline

Note: half values of the detection limits are used when metals are not detected

Values higher than the background mean + 2 x the standard deviation are highlighted in blue

Values higher than the CCME ASQG are highlighted in green

Values higher than the CCME ISQG are highlighted in red

Table 7: EXPLOSIVES IN SOILS BY HPLC IN PPM (NG and DNTs)

Sample	Lab No	NG	2,4-DNT	2,6-DNT
APELDORN GRENADE RANGE				
M-07-AGR-0-5m	M-07-1az	n.d.	n.d.	n.d.
	M-07-1bz	n.d.	n.d.	n.d.
M-07-AGR-5-10m	M-07-2az	n.d.	n.d.	n.d.
	M-07-2bz	n.d.	n.d.	n.d.
M-07-AGR-10-15m	M-07-3az	n.d.	n.d.	n.d.
	M-07-3bz	n.d.	n.d.	n.d.
M-07-AGR-10-15m dup	M-07-4az	n.d.	n.d.	n.d.
	M-07-4bz	n.d.	n.d.	n.d.
M-07-AGR-15-20m	M-07-5az	n.d.	n.d.	n.d.
	M-07-5bz	n.d.	n.d.	n.d.
M-07-AGR-20-25m	M-07-6az	n.d.	n.d.	n.d.
	M-07-6bz	n.d.	n.d.	n.d.
M-07-AGR-25-30m	M-07-7az	n.d.	n.d.	n.d.
CAEN				
M-07-CAEN-1	M-07-8az	**49.38**	**47.56**	**1.70**
	M-07-8a	**46.88**	**44.96**	n.d.
	M-07-8b	**41.28**	**39.04**	n.d.
M-07-CAEN-2	M-07-9az	**48.84**	**27.84**	**0.76**
	M-07-9a	**53.76**	**29.08**	n.d.
	M-07-9b	**47.16**	**23.84**	n.d.
M-07-CAEN-3	M-07-10az	**37.18**	**29.14**	**0.97**
	M-07-10a	**35.16**	**26.80**	n.d.
	M-07-10b	**67.24**	**47.96**	n.d.
	M-07-10c	**45.04**	**38.32**	n.d.
	M-07-10d	**49.12**	**34.88**	n.d.
M-07-CAEN-4	M-07-11az	**19.14**	**21.38**	**0.72**
	M-07-11a	**17.76**	**18.92**	n.d.
	M-07-11b	**31.64**	**35.60**	n.d.
	M-07-11cz	**27.74**	**32.74**	**1.13**
	M-07-11dz	**21.52**	**27.66**	**0.94**

Sample	Lab No	NG	2,4-DNT	2,6-DNT
M-07-CAEN-5	M-07-12az	**20.82**	**10.68**	**0.45**
	M-07-12a	**21.60**	**10.96**	n.d.
	M-07-12b	**13.44**	**6.84**	n.d.
	M-07-12cz	**15.18**	**9.29**	**0.27**
	M-07-12dz	**12.91**	**7.91**	**0.24**
M-07-CAEN-6	M-07-13az	**5.52**	**28.54**	**1.15**
	M-07-13a	**6.80**	**33.00**	n.d.
	M-07-13b	**3.32**	**17.72**	n.d.
CAMBRAI				
M-07-CAM-T1	M-07-14az	n.d.	n.d.	n.d.
	M-07-14bz	n.d.	**0.24**	n.d.
M-07-CAM-T1 dup	M-07-15az	n.d.	n.d.	n.d.
	M-07-15bz	n.d.	**0.23**	n.d.
M-07-CAM-T1 trip	M-07-16az	n.d.	n.d.	n.d.
	M-07-16bz	**2.25**	**0.08**	n.d.
M-07-CAM-T2	M-07-17az	**3.30**	n.d.	n.d.
	M-07-17bz	**4.44**	n.d.	n.d.
M-07-CAM-1-3 av	M-07-18az	**25.24**	**3.52**	n.d.
	M-07-18bz	**28.88**	**3.94**	n.d.
M-07-CAM-4-6 av	M-07-19az	**7.51**	**0.95**	n.d.
	M-07-19bz	**7.66**	**0.9**	n.d.
M-07-CAM-1-3 arr	M-07-20az	**4.72**	**0.62**	n.d.
	M-07-20bz	**4.85**	**0.63**	n.d.
M-07-CAM-4-6 arr	M-07-21az	**1.14**	**0.15**	n.d.
	M-07-21cz	**0.84**	n.d.	n.d.
	M-07-21dz	**2.16**	**0.26**	n.d.
CASSINO				
M-07-CAS-1	M-07-22az	n.d.	n.d.	n.d.
	M-07-22bz	n.d.	n.d.	n.d.
M-07-CAS-1 dup	M-07-23az	n.d.	n.d.	n.d.
	M-07-23bz	n.d.	n.d.	n.d.
M-07-CAS-2	M-07-24az	**0.89**	n.d.	n.d.
	M-07-24bz	**0.49**	n.d.	n.d.
M-07-CAS-3	M-07-25az	**0.27**	n.d.	n.d.

Sample	Lab No	NG	2,4-DNT	2,6-DNT
	M-07-25bz	**0.2**	n.d.	n.d.
DIEPPE				
M-07-DIEPPE-1	M-07-26az	**16.39**	**0.87**	n.d.
	M-07-26bz	**13.69**	**0.73**	n.d.
M-07-DIEPPE-2	M-07-27az	**4.77**	**0.21**	n.d.
	M-07-27bz	**6.31**	**0.28**	n.d.
M-07-DIEPPE-3	M-07-28az	**9.46**	**0.8**	n.d.
	M-07-28bz	**11.37**	**0.94**	n.d.
M-07-DIEPPE-4	M-07-29az	**7.21**	**0.12**	n.d.
	M-07-29bz	**6.92**	**0.11**	n.d.
M-07-DIEPPE-4 dup	M-07-30az	**6.33**	**0.11**	n.d.
	M-07-30bz	**7.42**	**0.15**	n.d.
M-07-DIEPPE-Pad	M-07-31az	**0.78**	**2.26**	n.d.
	M-07-31bz	**1.01**	**2.33**	n.d.
FIBUA ON ORTONA				
M-07-FIBUA-1	M-07-32az	**1.74**	n.d.	n.d.
	M-07-32bz	**1.64**	n.d.	n.d.
M-07-FIBUA-2	M-07-33az	**0.69**	n.d.	n.d.
	M-07-33bz	**0.44**	n.d.	n.d.
M-07-FIBUA-3	M-07-34az	**0.24**	n.d.	n.d.
	M-07-34bz	n.d.	n.d.	n.d.
GRAVENSTAFEL RIDGE SMALL ARMS RANGE				
M-07-GSR-FP-1-5	M-07-35az	**13.05**	**0.33**	n.d.
	M-07-35bz	**16.49**	**0.43**	n.d.
M-07-GSR-FP-6-10	M-07-36az	**13.3**	**0.09**	n.d.
	M-07-36cz	**9.62**	n.d.	n.d.
	M-07-36dz	**14.93**	n.d.	n.d.
MESSINES				
M-07-MES-OD-1	M-07-37az	**2.73**	**0.22**	n.d.
	M-07-37a	**2.84**	n.d.	n.d.
	M-07-37b	**4.88**	n.d.	n.d.
M-07-MES-OD-2	M-07-38az	n.d.	**0.64**	n.d.
	M-07-38cz	n.d.	**0.52**	n.d.
	M-07-38dz	n.d.	**0.20**	n.d.

Sample	Lab No	NG	2,4-DNT	2,6-DNT
M-07-MES-OD-2 dup	M-07-39az	n.d.	**0.25**	n.d.
	M-07-39a	n.d.	n.d.	n.d.
	M-07-39b	n.d.	n.d.	n.d.
M-07-MES-OD-3	M-07-40az	n.d.	n.d.	n.d.
	M-07-40bz	n.d.	n.d.	n.d.
NORMANDY				
M-07-NORM-1	M-07-41az	n.d.	n.d.	n.d.
	M-07-41bz	n.d.	n.d.	n.d.
M-07-NORM-2	M-07-42az	**0.72**	**0.08**	n.d.
	M-07-42bz	**0.57**	**0.07**	n.d.
M-07-NORM-3	M-07-43az	**0.18**	n.d.	n.d.
	M-07-43bz	**0.32**	n.d.	n.d.
M-07-NORM-4	M-07-44az	**0.29**	n.d.	n.d.
	M-07-44bz	**0.20**	n.d.	n.d.
M-07-NORM-4 dup	M-07-45az	n.d.	n.d.	n.d.
	M-07-45bz	n.d.	n.d.	n.d.
M-07-NORM-4 avant	M-07-46az	n.d.	n.d.	n.d.
	M-07-46bz	n.d.	n.d.	n.d.
URBAN ASSAULT RANGE NORTHEAST OF ORTONA				
M-07-ORT-1	M-07-47az	n.d.	n.d.	n.d.
	M-07-47bz	n.d.	n.d.	n.d.
M-07-ORT-2	M-07-48az	n.d.	n.d.	n.d.
	M-07-48bz	n.d.	n.d.	n.d.
M-07-ORT-3	M-07-49az	n.d.	n.d.	n.d.
	M-07-49bz	n.d.	n.d.	n.d.
M-07-ORT-4	M-07-50az	n.d.	n.d.	n.d.
	M-07-50bz	n.d.	n.d.	n.d.
PAARDEBURG ANTI-TANK RANGE				
M-07-PAT-A-0-5m	M-07-51a	**621.2**	n.d.	n.d.
	M-07-51b	**2828.4**	n.d.	n.d.
	M-07-51c	**2563.6**	n.d.	n.d.
	M-07-51d	**2978.0**	n.d.	n.d.
M-07-PAT-A-5-10m	M-07-52a	**442.8**	n.d.	n.d.
	M-07-52b	**2736.8**	n.d.	n.d.

Sample	Lab No	NG	2,4-DNT	2,6-DNT
	M-07-52c	**2071.2**	n.d.	n.d.
	M-07-52d	**2384.8**	n.d.	n.d.
M-07-PAT-A-10-15m	M-07-53a	**191.2**	n.d.	n.d.
	M-07-53b	**846.0**	n.d.	n.d.
	M-07-53c	**1180.8**	n.d.	n.d.
	M-07-53d	**982.4**	n.d.	n.d.
M-07-PAT-A-15-20m	M-07-54az	**169.2**	**0.73**	n.d.
	M-07-54a	**178.20**	n.d.	n.d.
	M-07-54b	**203.04**	n.d.	n.d.
M-07-PAT-B-0-5m	M-07-55a	**826.0**	n.d.	n.d.
	M-07-55bz	**155.6**	n.d.	n.d.
	M-07-55c	**3306.4**	n.d.	n.d.
	M-07-55d	**3974.4**	n.d.	n.d.
M-07-PAT-B-5-10m	M-07-56a	**519.2**	n.d.	n.d.
	M-07-56b	**2354.4**	n.d.	n.d.
	M-07-56c	**2414.4**	n.d.	n.d.
	M-07-56d	**2240.0**	n.d.	n.d.
M-07-PAT-B-10-15m	M-07-57az	**201.7**	n.d.	n.d.
	M-07-57a	**1358.4**	n.d.	n.d.
	M-07-57b	**784.0**	n.d.	n.d.
	M-07-57c	**860.0**	n.d.	n.d.
	M-07-57d	**841.6**	n.d.	n.d.
M-07-PAT-B-15-20m	M-07-58az	**108.9**	n.d.	n.d.
	M-07-58a	**131.96**	n.d.	n.d.
	M-07-58b	**174.40**	n.d.	n.d.
M-07-PAT-T1	M-07-59a	**28.16**	n.d.	n.d.
	M-07-59bz	**117.2**	n.d.	n.d.
	M-07-59c	**118.16**	n.d.	n.d.
	M-07-59d	**105.04**	n.d.	n.d.
M-07-PAT-T2	M-07-60az	**1.94**	**0.32**	n.d.
	M-07-60bz	**6.44**	n.d.	n.d.
	M-07-60cz	**4.17**	n.d.	n.d.
	M-07-60dz	**5.38**	n.d.	n.d.
M-07-PAT-T3	M-07-61a	**40.72**	n.d.	n.d.

Sample	Lab No	NG	2,4-DNT	2,6-DNT
	M-07-61b	**244.4**	n.d.	n.d.
	M-07-61c	**328.4**	n.d.	n.d.
	M-07-61d	**382.8**	n.d.	n.d.
PUSAN				
M-07-PUSAN	M-07-62az	**7.07**	**5.31**	**0.2**
	M-07-62bz	**6.65**	**4.62**	n.d.
ROAD CROSSING				
M-07-RC-1	M-07-63az	n.d.	n.d.	n.d.
	M-07-63bz	n.d.	n.d.	n.d.
M-07-RC-2	M-07-64az	n.d.	n.d.	n.d.
	M-07-64bz	n.d.	n.d.	n.d.
GULLY SMALL ARMS RANGE				
M-07-RG-FP-100m-1-12	M-07-65a	**21.16**	n.d.	n.d.
	M-07-65bz	**74.00**	n.d.	n.d.
	M-07-65c	**138.30**	n.d.	n.d.
	M-07-65d	**91.72**	n.d.	n.d.
M-07-RG-FP-100m-13-24	M-07-66az	**34.2**	**0.26**	n.d.
	M-07-66bz	**52.9**	**0.37**	n.d.
M-07-RG-FP-300m-1-12	M-07-67az	**1.94**	n.d.	n.d.
	M-07-67bz	**3.11**	n.d.	n.d.
M-07-RG-FP-300m-13-24	M-07-68az	**0.49**	n.d.	n.d.
	M-07-68bz	n.d.	n.d.	n.d.
ALPHA SMALL ARMS RANGE				
M-07-SAR-FP-1-9	M-07-69az	**23.84**	**0.12**	n.d.
	M-07-69bz	**54.58**	**0.29**	n.d.
	M-07-69cz	**52.72**	**0.25**	n.d.
	M-07-69dz	**46.34**	**0.22**	n.d.
M-07-SAR-FP-10-18	M-07-70az	**16.94**	n.d.	n.d.
	M-07-70bz	**28.88**	**0.24**	n.d.
	M-07-70cz	**26.96**	**0.30**	n.d.
	M-07-70dz	**24.58**	**0.10**	n.d.
M-07-SAR-FP-10-18 dup	M-07-71az	**18.26**	n.d.	n.d.
	M-07-71bz	**30.96**	n.d.	n.d.
	M-07-71c	**26.24**	n.d.	n.d.

Sample	Lab No	NG	2,4-DNT	2,6-DNT
	M-07-71d	**40.24**	n.d.	n.d.
M-07-SAR-FP-19-27	M-07-72az	**1.32**	n.d.	n.d.
	M-07-72bz	**1.3**	n.d.	n.d.
M-07-SAR-FP-28-36	M-07-73az	**0.93**	n.d.	n.d.
	M-07-73bz	**1.12**	n.d.	n.d.
SKEET RANGE				
M-07-SKEET-FP-1	M-07-74az	n.d.	n.d.	n.d.
	M-07-74bz	n.d.	n.d.	n.d.
M-07-SKEET-FP-1 dup	M-07-75az	n.d.	n.d.	n.d.
	M-07-75bz	n.d.	n.d.	n.d.
SPECIAL UNIT				
M-07-US1 (0-30m)	M-07-76az	n.d.	n.d.	n.d.
	M-07-76bz	n.d.	n.d.	n.d.
M-07-US1 (0-30m) dup	M-07-77az	n.d.	n.d.	n.d.
	M-07-77bz	n.d.	n.d.	n.d.
M-07-US2 (30-60m)	M-07-78az	n.d.	n.d.	n.d.
	M-07-78bz	n.d.	n.d.	n.d.
M-07-US2 (30-60m) dup	M-07-79az	n.d.	n.d.	n.d.
	M-07-79bz	n.d.	n.d.	n.d.

n.d.: not detected

Table 8: EXPLOSIVES IN SOILS BY HPLC IN PPM (TNT, RDX, HMX and ADNTs)

Sample	Lab No	TNT	RDX	HMX	2-ADNT	4-ADNT
APELDORN GRENAGE RANGE						
M-07-AGR-0-5m	M-07-1az	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-1bz	n.d.	**0.12**	n.d.	n.d.	n.d.
M-07-AGR-5-10m	M-07-2az	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-2bz	n.d.	n.d.	n.d.	n.d.	n.d.
M-07-AGR-10-15m	M-07-3az	n.d.	**0.04**	n.d.	n.d.	n.d.
	M-07-3bz	n.d.	**0.04**	n.d.	n.d.	n.d.
M-07-AGR-10-15m dup	M-07-4az	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-4bz	n.d.	n.d.	n.d.	n.d.	n.d.
M-07-AGR-15-20m	M-07-5az	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-5bz	n.d.	n.d.	n.d.	n.d.	n.d.
M-07-AGR-20-25m	M-07-6az	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-6bz	n.d.	n.d.	n.d.	n.d.	n.d.
M-07-AGR-25-30m	M-07-7az	n.d.	n.d.	n.d.	n.d.	n.d.
M-07-AGR-0-5m	M-07-1az	n.d.	n.d.	n.d.	n.d.	n.d.
CAEN						
M-07-CAEN-1	M-07-8az	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-8a	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-8b	n.d.	n.d.	n.d.	n.d.	n.d.
M-07-CAEN-2	M-07-9az	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-9a	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-9b	n.d.	n.d.	n.d.	n.d.	n.d.
M-07-CAEN-3	M-07-10az	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-10a	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-10b	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-10c	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-10d	n.d.	n.d.	n.d.	n.d.	n.d.
M-07-CAEN-4	M-07-11az	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-11a	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-11b	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-11cz	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-11dz	n.d.	n.d.	n.d.	n.d.	n.d.

Sample	Lab No	TNT	RDX	HMX	2-ADNT	4-ADNT
M-07-CAEN-5	M-07-12az	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-12a	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-12b	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-12cz	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-12dz	n.d.	n.d.	n.d.	n.d.	n.d.
M-07-CAEN-6	M-07-13az	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-13a	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-13b	n.d.	n.d.	n.d.	n.d.	n.d.
CAMBRAI						
M-07-CAM-T1	M-07-14az	n.d.	n.d.	**1.55**	n.d.	n.d.
	M-07-14bz	n.d.	n.d.	**1.88**	n.d.	n.d.
M-07-CAM-T1 dup	M-07-15az	n.d.	n.d.	**0.57**	n.d.	n.d.
	M-07-15bz	n.d.	n.d.	**0.58**	n.d.	n.d.
M-07-CAM-T1 trip	M-07-16az	n.d.	n.d.	**0.49**	n.d.	n.d.
	M-07-16bz	n.d.	n.d.	**0.41**	n.d.	n.d.
M-07-CAM-T2	M-07-17az	n.d.	n.d.	**3.46**	n.d.	n.d.
	M-07-17bz	n.d.	n.d.	**4.53**	n.d.	n.d.
M-07-CAM-1-3 av	M-07-18az	n.d.	n.d.	**0.40**	n.d.	n.d.
	M-07-18bz	n.d.	n.d.	**0.14**	n.d.	n.d.
M-07-CAM-4-6 av	M-07-19az	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-19bz	n.d.	n.d.	n.d.	n.d.	n.d.
M-07-CAM-1-3 arr	M-07-20az	n.d.	**0.29**	n.d.	n.d.	n.d.
	M-07-20bz	n.d.	**0.89**	n.d.	n.d.	n.d.
M-07-CAM-4-6 arr	M-07-21az	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-21cz	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-21dz	n.d.	n.d.	n.d.	n.d.	n.d.
CASSINO						
M-07-CAS-1	M-07-22az	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-22bz	n.d.	n.d.	n.d.	n.d.	n.d.
M-07-CAS-1 dup	M-07-23az	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-23bz	n.d.	n.d.	n.d.	n.d.	n.d.
M-07-CAS-2	M-07-24az	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-24bz	n.d.	n.d.	n.d.	n.d.	n.d.
M-07-CAS-3	M-07-25az	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-25bz	n.d.	n.d.	n.d.	n.d.	n.d.

Sample	Lab No	TNT	RDX	HMX	2-ADNT	4-ADNT
DIEPPE						
M-07-DIEPPE-1	M-07-26az	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-26bz	n.d.	n.d.	n.d.	n.d.	n.d.
M-07-DIEPPE-2	M-07-27az	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-27bz	n.d.	n.d.	n.d.	n.d.	n.d.
M-07-DIEPPE-3	M-07-28az	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-28bz	n.d.	n.d.	n.d.	n.d.	n.d.
M-07-DIEPPE-4	M-07-29az	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-29bz	n.d.	n.d.	n.d.	n.d.	n.d.
M-07-DIEPPE-4 dup	M-07-30az	n.d.	**0.25**	n.d.	n.d.	n.d.
	M-07-30bz	n.d.	n.d.	n.d.	n.d.	n.d.
M-07-DIEPPE-Pad	M-07-31az	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-31bz	n.d.	n.d.	n.d.	n.d.	n.d.
FIBUA ON ORTONA						
M-07-FIBUA-1	M-07-32az	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-32bz	n.d.	n.d.	n.d.	n.d.	n.d.
M-07-FIBUA-2	M-07-33az	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-33bz	n.d.	n.d.	n.d.	n.d.	n.d.
M-07-FIBUA-3	M-07-34az	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-34bz	n.d.	n.d.	n.d.	n.d.	n.d.
GRAVENSTAFEL RIDGE SMALL ARMS RANGE						
M-07-GSR-FP-1-5	M-07-35az	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-35bz	n.d.	n.d.	n.d.	n.d.	n.d.
M-07-GSR-FP-6-10	M-07-36az	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-36cz	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-36dz	n.d.	n.d.	n.d.	n.d.	n.d.
MESSINES						
M-07-MES-OD-1	M-07-37az	**3.93**	**37.98**	**3.05**	**0.79**	**0.55**
	M-07-37a	**3.6**	**34.28**	**3.00**	n.d.	n.d.
	M-07-37b	**4.16**	**42.04**	**3.68**	n.d.	n.d.
M-07-MES-OD-2	M-07-38az	**1.54**	**13.72**	**1.22**	**0.25**	**0.17**
	M-07-38cz	**0.88**	**9.19**	**0.81**	n.d.	n.d.
	M-07-38dz	**0.91**	**9.25**	**0.80**	n.d.	n.d.
M-07-MES-OD-2 dup	M-07-39az	**1.7**	**80.78**	**6.04**	n.d.	n.d.
	M-07-39a	**1.76**	**77.84**	**5.56**	n.d.	n.d.

Sample	Lab No	TNT	RDX	HMX	2-ADNT	4-ADNT
	M-07-39b	n.d.	**74.2**	**5.36**	n.d.	n.d.
M-07-MES-OD-3	M-07-40az	n.d.	**0.28**	n.d.	n.d.	n.d.
	M-07-40bz	n.d.	**0.32**	n.d.	n.d.	n.d.
NORMANDY						
M-07-NORM-1	M-07-41az	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-41bz	n.d.	n.d.	n.d.	n.d.	n.d.
M-07-NORM-2	M-07-42az	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-42bz	n.d.	n.d.	n.d.	n.d.	n.d.
M-07-NORM-3	M-07-43az	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-43bz	n.d.	n.d.	n.d.	n.d.	n.d.
M-07-NORM-4	M-07-44az	**0.27**	n.d.	n.d.	n.d.	n.d.
	M-07-44bz	n.d.	n.d.	n.d.	n.d.	n.d.
M-07-NORM-4 dup	M-07-45az	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-45bz	n.d.	n.d.	n.d.	n.d.	n.d.
M-07-NORM-4 avant	M-07-46az	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-46bz	n.d.	n.d.	n.d.	n.d.	n.d.
URBAN ASSAULT RANGE NORTHEAST OF ORTONA						
M-07-ORT-1	M-07-47az	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-47bz	n.d.	n.d.	n.d.	n.d.	n.d.
M-07-ORT-2	M-07-48az	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-48bz	n.d.	n.d.	n.d.	n.d.	n.d.
M-07-ORT-3	M-07-49az	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-49bz	n.d.	n.d.	n.d.	n.d.	n.d.
M-07-ORT-4	M-07-50az	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-50bz	n.d.	n.d.	n.d.	n.d.	n.d.
PAARDEBURG ANTI-TANK RANGE						
M-07-PAT-A-0-5m	M-07-51a	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-51b	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-51c	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-51d	n.d.	n.d.	n.d.	n.d.	n.d.
M-07-PAT-A-5-10m	M-07-52a	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-52b	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-52c	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-52d	n.d.	n.d.	n.d.	n.d.	n.d.
M-07-PAT-A-10-15m	M-07-53a	n.d.	n.d.	n.d.	n.d.	n.d.

Sample	Lab No	TNT	RDX	HMX	2-ADNT	4-ADNT
	M-07-53b	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-53c	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-53d	n.d.	n.d.	n.d.	n.d.	n.d.
M-07-PAT-A-15-20m	M-07-54az	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-54a	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-54b	n.d.	n.d.	n.d.	n.d.	n.d.
M-07-PAT-B-0-5m	M-07-55a	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-55bz	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-55c	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-55d	n.d.	n.d.	n.d.	n.d.	n.d.
M-07-PAT-B-5-10m	M-07-56a	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-56b	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-56c	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-56d	n.d.	n.d.	n.d.	n.d.	n.d.
M-07-PAT-B-10-15m	M-07-57az	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-57a	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-57b	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-57c	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-57d	n.d.	n.d.	n.d.	n.d.	n.d.
M-07-PAT-B-15-20m	M-07-58az	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-58a	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-58b	n.d.	n.d.	n.d.	n.d.	n.d.
M-07-PAT-T1	M-07-59a	n.d.	n.d.	**8.84**	n.d.	n.d.
	M-07-59bz	n.d.	n.d.	**32.62**	n.d.	n.d.
	M-07-59c	n.d.	n.d.	**26.56**	n.d.	n.d.
	M-07-59d	n.d.	n.d.	**23.60**	n.d.	n.d.
M-07-PAT-T2	M-07-60az	n.d.	n.d.	**6.75**	n.d.	n.d.
	M-07-60bz	n.d.	n.d.	**12.21**	n.d.	n.d.
	M-07-60cz	n.d.	n.d.	**11.23**	n.d.	n.d.
	M-07-60dz	n.d.	n.d.	**11.70**	n.d.	n.d.
M-07-PAT-T3	M-07-61a	n.d.	n.d.	**236.84**	n.d.	n.d.
	M-07-61b	n.d.	n.d.	**913.2**	n.d.	n.d.
	M-07-61c	n.d.	n.d.	**1169.2**	n.d.	n.d.
	M-07-61d	n.d.	n.d.	**1339.2**	n.d.	n.d.
PUSAN						

Sample	Lab No	TNT	RDX	HMX	2-ADNT	4-ADNT
M-07-PUSAN	M-07-62az	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-62bz	n.d.	n.d.	n.d.	n.d.	n.d.
ROAD CROSSING						
M-07-RC-1	M-07-63az	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-63bz	n.d.	n.d.	n.d.	n.d.	n.d.
M-07-RC-2	M-07-64az	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-64bz	n.d.	n.d.	n.d.	n.d.	n.d.
GULLY SMALL ARMS RANGE						
M-07-RG-FP-100m-1-12	M-07-65a	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-65bz	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-65c	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-65d	n.d.	n.d.	n.d.	n.d.	n.d.
M-07-RG-FP-100m-13-24	M-07-66az	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-66bz	n.d.	n.d.	n.d.	n.d.	n.d.
M-07-RG-FP-300m-1-12	M-07-67az	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-67bz	n.d.	n.d.	n.d.	n.d.	n.d.
M-07-RG-FP-300m-13-24	M-07-68az	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-68bz	n.d.	n.d.	n.d.	n.d.	n.d.
ALPHA SMALL ARMS RANGE						
M-07-SAR-FP-1-9	M-07-69az	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-69bz	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-69cz	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-69dz	n.d.	n.d.	n.d.	n.d.	n.d.
M-07-SAR-FP-10-18	M-07-70az	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-70bz	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-70cz	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-70dz	n.d.	n.d.	n.d.	n.d.	n.d.
M-07-SAR-FP-10-18 dup	M-07-71az	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-71bz	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-71c	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-71d	n.d.	n.d.	n.d.	n.d.	n.d.
M-07-SAR-FP-19-27	M-07-72az	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-72bz	n.d.	n.d.	n.d.	n.d.	n.d.
M-07-SAR-FP-28-36	M-07-73az	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-73bz	n.d.	n.d.	n.d.	n.d.	n.d.

Sample	Lab No	TNT	RDX	HMX	2-ADNT	4-ADNT
SKEET						
M-07-SKEET-FP-1	M-07-74az	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-74bz	n.d.	n.d.	n.d.	n.d.	n.d.
M-07-SKEET-FP-1 dup	M-07-75az	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-75bz	n.d.	n.d.	n.d.	n.d.	n.d.
SPECIAL UNIT						
M-07-US1 (0-30m)	M-07-76az	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-76bz	n.d.	n.d.	n.d.	n.d.	n.d.
M-07-US1 (0-30m) dup	M-07-77az	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-77bz	n.d.	n.d.	n.d.	n.d.	n.d.
M-07-US2 (30-60m)	M-07-78az	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-78bz	n.d.	n.d.	n.d.	n.d.	n.d.
M-07-US2 (30-60m) dup	M-07-79az	n.d.	n.d.	n.d.	n.d.	n.d.
	M-07-79bz	n.d.	n.d.	n.d.	n.d.	n.d.

n.d.: not detected

All nitrotoluenes, 1,3,5-trinitrobenzene, 1,3 dinitrobenzene and tetryl were not detected in any samples

Table 9: PAHS IN SOILS AT THE SKEET RANGE IN PPM

Parameters	1	2	3	4	5	6	BL
Acenaphthene	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Acenaphthylene	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Anthracene	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Benzo(a)anthracene	**0.89**	**0.04**	**0.18**	**0.09**	**0.02**	**0.90**	**1.70**
Benzo(a)pyrene	**1.00**	**0.07**	**0.24**	**0.11**	**0.02**	**1.40**	**2.00**
Benzo(b/j)fluoranthene	**0.51**	**0.04**	**0.08**	**0.06**	**0.01**	**0.80**	**0.77**
Benzo(g,h,i)perylene	**0.42**	**0.03**	**0.10**	**0.05**	n.d.	**0.60**	**0.80**
Benzo(k)fluoranthene	**0.07**	n.d.	n.d.	n.d.	n.d.	n.d.	**0.11**
Chrysene	**1.00**	**0.11**	**0.30**	**0.21**	**0.03**	**1.00**	**1.4**
Dibenz(a,h)anthracene	**0.24**	n.d.	n.d.	**0.03**	n.d.	n.d.	**0.30**
Fluoranthene	n.d.	n.d.	**0.01**	n.d.	n.d.	n.d.	**0.08**
Fluorene	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Indeno(1,2,3-cd)pyrene	**0.11**	n.d.	n.d.	n.d.	n.d.	n.d.	**0.20**
1-Methylnaphthalene	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
2-Methylnaphthalene	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Naphthalene	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Phenanthrene	n.d.	n.d.	**0.01**	n.d.	n.d.	n.d.	**0.08**
Pyrene	**0.20**	**0.01**	**0.17**	**0.02**	**0.01**	n.d.	**1.10**
Moisture %	**21.0**	**16.0**	**18.0**	**14.0**	**14.0**	**12.0**	**11.0**

All samples are Skeet range samples M-07-Skeet-1 to M-07-Skeet-6 and M-07-Skeet –BL. The detection limits for all these analytes can be found in the Maxxam Analytical Lab files in Annex A.

References

[1] Ampleman, G., Thiboutot, S., Gagnon, A., Marois, A., Martel, R, and Lefebvre, R., "Study of the Impacts of OB/OD Activity on Soils and Groundwater at the Destruction Area in CFAD Dundurn"; DREV R-9827, December 1998.

[2] Thiboutot, S., Ampleman, G., Gagnon, A., Marois, A., Jenkins, T.F., Walsh, M.E., Thorne, P.G. and Ranney, T.A., "Characterisation of Antitank Firing Ranges at CFB Valcartier, WATC Wainwright and CFAD Dundurn"; DREV R-9809, October 1998.

[3] US EPA 1993, "Approaches for the Remediation of Federal Facility Sites Contaminated with Explosives or Radioactive Wastes"; EPA Handbook # EPA/625/R-93/013, September 1993.

[4] Checkai, R.T., Major, M.A., Nwanguma, R.O., Phillips, C.T. and Sadusky, M.C., "Transport and Fate of Nitroaromatic and Nitramine Explosives in Soils From Open Burning/Open Detonation Operations"; Edgewood Research Development & Engineering Center, report ERDEC-TR-136, December 1993.

[5] Thiboutot, S., Ampleman, G., Jenkins, T.F., Walsh, M.E., Thorne, P.G., Ranney, T.A. and Grant, G.L., "Assessment of Sampling Strategy for Explosives-Contaminated Soils"; Proceedings of the 90th Annual Air and Waste Management Society Meeting, Paper # 94-WP 101.08, Toronto, June 1997.

[6] Jenkins, T.F., Walsh, M.E., Thorne, P.G., Thiboutot, S, Ampleman, G., Ranney, T.A. and Grant, C.L., "Assessment of Sampling Error Associated with Collection and Analysis of Soil Samples at a Firing Range Contaminated with HMX"; CRREL Special Report # 97-22, September 1997.

[7] Jenkins, T.F., Walsh, M.E., Thorne, P.G., Miyares, P.H., Ranney, T.A., Grant, C.L. and Esparza, J.R., "Site Characterization for Explosives Contamination at a Military Firing Range Impact Area"; CRREL Special Report 98-9, 1998.

[8] Jenkins, T.F., Thiboutot, S., Ampleman, G., Grant, C.L., Thorne, P.G., Walsh, M.E., Esparza, J.R., Ranney, T.A. and Stutz, M.H., "Sampling and Analytical Considerations for Site Characterization at Military Firing Ranges"; Proceedings of the 2nd Biennial International Conference on Chemical Measurement and Monitoring of the Environment, May 11-14, 1998, Ottawa, Canada. EnviroAnalysis '98 (Eds. Ray Clement and Bob Burk). Ottawa, Ontario: Carleton University, p. 37-42. (MP 5142).

[9] Brannon, J.M., Jenkins, T.F., Parker, L.V., Deliman, P., Gerald, J.A., Ruiz, C., Porter, B. and Davis, W.M., "Procedures for Determining Integrity of UXO and Explosives Soil Contamination at Firing Ranges"; ERDC Technical Report; ERDC TR-00-4. (ERDC/CRREL MP-01-5604), 2000.

[10] Walsh, M.E., Collins, C.M., Racine, C.H., Jenkins, T.F., Gelvin, A.B. and Ranney, T.A., "Sampling for Explosives Residues at Fort Greely, Alaska"; Reconnaissance visit July 2000. ERDC/CRREL TR-01-15, 2001.

[11] Pennington, J.C., Jenkins, T.F., Brannon, J.M., Lynch, J., Ranney, T.A., Berry, T.E. Jr., Hayes, C.A., Miyares, P.H., Walsh, M.E., Hewitt, A.D., Perron, N. and Delfino, J.J., "Distributional and Fate of Energetics on DoD Test and Training Ranges: Interim Report 1"; Engineer Research and Development Center. Technical Report, ERDC TR-01-13, 2001.

[12] Jenkins, T.F., Walsh, M.E., Thorne, P.G., Thiboutot, S., Ampleman, G., Ranney, T.A. and Grant, C.L., "Assessment of Sampling Error Associated with Collection and Analysis of Soil Samples at a Firing Range Contaminated with HMX". CRREL Special Report 97-22, 1997.

[13] Ampleman, G., Thiboutot, S., Désilets, S., Gagnon, A. and Marois, A., "Evaluation of the Soils Contamination by Explosives at CFB Chilliwack and CFAD Rocky Point"; DREV Report TR-2000-103, November 2000.

[14] Thiboutot, S., Ampleman, G., Gagnon, A. and Marois, A., "Characterisation of an Unexploded Ordnance Contaminated Range (Tracadie Range) for Potential Contamination by Energetic Materials"; DREV Report TR-2000-102, November 2000.

[15] Ampleman, G., Thiboutot, S., Lewis, J., Marois, A., Gagnon, A., Bouchard, M., Jean, S., Jenkins, T., Hewitt, A., Pennington, J. and Ranney, T.A., "Evaluation of the Contamination by Explosives in Soils, Biomass and Surface Water at Cold Lake Air Weapons Range (CLAWR), Alberta, Phase I Report"; DRDC Valcartier TR 2003-208, December 2003.

[16] Ampleman, G., Thiboutot, S., Lewis, J., Marois, A. Gagnon, A., Bouchard, M., Jenkins, T.F., Ranney, T.A., and Pennington, J.C., "Evaluation of the Contamination by Explosives and Metals in Soils, Vegetation, Surface Water and Sediment at Cold Lake Air Weapons Range (CLAWR), Alberta, Phase II, Final report"; DRDC-Valcartier TR 2004-204, November 2004.

[17] Thiboutot, S., Ampleman, G., Dubé, P., Jenkins, T.F., Walsh, M.E., Hawari, J., Spencer, B. and Paquet, L., "Protocol for the Characterisation of Explosives Contaminated Sites"; DREV R-9721, April 1998.

[18] Thiboutot, S., Ampleman, G. and Hewitt, A.D., "Guide for Characterization of Sites Contaminated with Energetic Materials". ERDC/CRREL TR-02-1, 2002.

[19] Jenkins, T.F. and Walsh, M.E., "Development of an Analytical Method for Explosive Residues in Soil"; CRREL Report 87-7, U.S.A.T.H.M.A., Report # AMXTH-TE-FR-86102, June 1987.

[20] Cragin, J.H., Legget, D.C., Foley, B.T. and Schumacher, P.W., "TNT, RDX and HMX Explosives in Soils and Sediment, Analysis Techniques and Drying Losses"; U.S.A.T.H.M.A. Report # AMX-TH-TE-FR-85038, October 1985.

[21] Selim, H.M. and Iskandar, I.K., "Sorption-Desorption and Transport of TNT and RDX in Soils"; CRREL Report AD-A-285-570, May 1994.

[22] Fellows, R.S., Harvey, S.D. and Cataldo, D.A., "An Evaluation of the Environmental Fate and Behaviour of Munitions Material (TNT Metabolites) in Soil and Plant System"; Contract DE-AC06-76RLO 1830, November 1992.

[23] Walsh, M.E. and Ranney, T.A., "Determination of Nitroaromatic, Nitramine, and Nitrate Ester Explosives in Water Using SPE and GC-ECD: Comparison with HPLC"; CRREL Report 98-2, 1998.

[24] Walsh, M. E., and Ranney, T., "Determination of Nitroaromatic, Nitramine, and Nitrate Ester Explosives in Water Using Solid-Phase Extraction and Gas Chromatography-Electron Capture Detection: Comparison with High-Performance Liquid Chromatography"; J. Chromatogr. Sc., 36(8): 406-416, 1998.

[25] Walsh, M.E., "Determination of Nitroaromatic, Nitramine, and Nitrate Ester Explosives in Soil by Gas Chromatography and an Electron Capture Detector"; Talanta, 54: 427-438, 2001. (ERDC/CRREL MP-02-5774).

[26] Jenkins, T.F., Grant, C.L. Brar, G.S. Thorne, P.G. Schumacher P.W. and Ranney T.A., "Sampling Error Associated with Collection and Analysis of Soil Samples at TNT-Contaminated Sites". Field Analytical Chemistry and Technology, 1(3): 151-163, 1997.

[27] Walsh, M.E. and Ranney, T.A., "Determination of Nitroaromatic, Nitramine, and Nitrate Ester Explosives in Soils Using GC-ECD"; CRREL Report 99-12, 1999.

[28] Pennington, J. C., Jenkins, T. F., Thiboutot, S., Ampleman, G., Clausen, J., Hewitt, A. D., Lewis, J., Walsh, M. R., Ranney, T. A., Silverblatt, B., Marois A., Gagnon, A., Brousseau, P., Zufelt, J. E., Poe, K., Bouchard, M., Martel, R., Lewis, J., Walker, D. D., Ramsey, C. A., Hayes, C. A., Yost, S., Bjella, K. L., Trepanier, L., Berry, T. E., Lambert, D. J., Dubé, P., and Perron, N. M., "Distribution and Fate of Energetics on DoD Test and Training Ranges: Report 5," ERDC TR-05-02, U. S. Army Engineer Research and Development Center, Environmental Laboratory, Vicksburg, MS, April 2005.

[29] Brochu, S., Diaz, E., Thiboutot, S., Ampleman, G., Hewitt, A.D., Bigl, S.R., Walsh, M., Bjella, K., Ranney, T., Walsh, M., Taylor, S., Ramsey, C., Lambert, D. and Perron, N., "Assessment of 100 Years of Military Training in Canada: The Case of Canadian Force Base Petawawa"; Chapter 3, Distribution and Fate of Energetics on DoD Test and Training Ranges: Report 6, ERDC TR-06-12, U. S. Army Engineer Research and Development Center, Environmental Laboratory, Vicksburg, MS, December 2005.

[30] Diaz, E., Brochu, S., Thiboutot, S., Ampleman, G., Marois, A. and Gagnon, A., "Assessment of Contamination by Energetic Materials and Metals in Soils and Biomasses at Western Area Training Center (WATC) in Wainwright, Alberta (Phase I)"; Chapter 4, Distribution and Fate of Energetics on DoD Test and Training Ranges: Report 6, ERDC TR-06-12, U. S. Army Engineer Research and Development Center, Environmental Laboratory, Vicksburg, MS, December 2005.

[31] Thiboutot, S., Ampleman, G., Marois A., Gagnon, A, Bouchard, M., Hewitt, A., Jenkins, T. F., Walsh, M., Bjella, K., Ramsey, C., and Ranney, T. A., "Environmental Conditions of Surface Soils, CFB Gagetown Training Area: Delineation of the Presence of Munitions Related Residues (Phase III, Final Report)"; DRDC Valcartier TR 2004-205, November 2004.

[32] Marois, A., Gagnon, A., Thiboutot, S., Ampleman, G. et Bouchard, M., "Caractérisation des sols de surface et de la biomasse dans les secteurs d'entraînement, Base des Forces Canadiennes, Valcartier"; DRDC Valcartier TR-2004-206, November 2004.

[33] Pennington, J.C., Jenkins, T.F., Ampleman, G., Thiboutot, S., Brannon, J., Clausen, J., Hewitt,A.D., Brochu, S., Dubé, P., Lewis, J., Ranney T.A, Faucher, D., Gagnon, A., Stark, J.A., Brousseau, P., Price, C.B., Lambert, D., Marois, A., Bouchard, M., Walsh, M.E., Yost, S.L., Perron, N.M., Martel, R., Jean, S., Taylor, S., Hayes, C.A., Ballard, J.M., Walsh, M.R., Mirecki, J.E., Downe, S., Collins, N.H., Porter, B., and Karn, R., "Distribution and Fate of Energetics on DoD Test and Training Ranges; Interim Report 4" ERDC TR-04-4, November 2004.

[34] Ampleman, G., Thiboutot, S., Lewis, J., Marois, A., Gagnon, A., Bouchard, M., Martel, R., Lefebvre, R., Gauthier, C., Ballard, J.M., Jenkins, T., Ranney, T. and Pennington, J., "Evaluation of the Impacts of Live Fire Training at CFB Shilo (Final Report)"; DRDC Valcartier TR 2003-066, 2003.

[35] Thiboutot, S., Ampleman, G., Lewis, J., Faucher, D., Martel, R., Ballard, J.M., Downe, S, Jenkins, T., Hewitt, A. and Pennington, J.,"Environmental Conditions of Surface Soils and Biomass Prevailing in the Training Area at CFB Gagetown, New Brunswick"; DRDC Valcartier TR-2003-152, 2003.

[36] Thiboutot, S., Ampleman, G., Martel, R., Lefebvre, R. and Paradis, D., "Environmental Characterization of Canadian Forces Base Shilo Training Area (Battleruns) Following Gates Closure"; DREV TR-2001-126, 2001.

[37] Jenkins, T.F., Thiboutot, S., Ampleman, G., Hewitt, A.D., Walsh, M.E., Ranney, T.A., Ramsey, C.A., Grant, C.L., Collins, C.M., Brochu, S., Bigl, S.R. and Pennington, J.C., "Identity and Distribution of Residues of Energetic Compounds at Military Live-Fire Training Ranges"; ERDC TR-05-10, November 05.

[38] Pennington, J., Jenkins, T., Ampleman, G., Thiboutot, S., Brannon, J., Lewis, J., DeLaney, J., Clausen, J., Hewitt, A., Hollander, M., Hayes, C., Stark, J., Marois, A., Brochu, S., Dinh, H., Lambert, D., Gagnon, A., Bouchard, M., Martel, R., Brousseau, P., Perron, N., Lefebvre, R., Davis, W., Ranney, T.A., Gauthier, C., Taylor, S. and Ballard, J.M., "Distribution and Fate of Energetics on DoD Test and Training Ranges: Interim Report 3"; SERDP interim Report, ERDC TR-03-2, September 2003.

[39] Pennington, J. C., Jenkins, T. F., Ampleman, G., Thiboutot, S., Brannon, J. M., Lynch, J., Ranney, T. A., Stark, J. A., Walsh, M. E., Lewis, J., Hayes, C. A., Mirecki, J. E., Hewitt, A. D., Perron, N., Lambert, D., Clausen, J., and Delfino, J. J., "Distribution and Fate of Energetics on DoD Test and Training Ranges: Interim Report 2," ERDC TR-02-8, U.S. Army Engineer Research and Development Center, Vicksburg, MS, November 2002.

[40] Pennington, J., Jenkins, T., Ampleman, G., Thiboutot, S., Brannon, J., Lynch, J., Ranney, T., Stark, J., Walsh, M., Lewis, J., Hayes, C., Mirecki, J., Hewitt, A., Perron, N., Lambert, D., Clausen, J. and Delfino, J., "Distribution and Fate of Energtic on DoD Test and Training Ranges: Interim Report 1"; Engineer R & D Center, US Army Corps of Engineers, ERDC TR-01-13, October 2002.

[41] Jenkins, T.F., Pennington, J.C., Ranney, T.A., Berry, Jr., T.E., Miyares, P.H., Walsh, M.E., Hewitt, A.D., Perron, N., Parker, L.V., Hayes, C.A. and Maj. Wahlgren, E., "Characterization of Explosives Contamination at Military Firing Ranges"; ERDC TR-01-05, July 2001.

[42] Jenkins, T.F., Hewitt, A.D., Grant, C.L., Thiboutot, S., Ampleman, G., Walsh, M.E., Ranney, T.A., Ramsey, C.A. Palazzo, A.J. and Pennington, J.C., "Identity and Distribution of Residues of Energetic Compounds at Army Live-Fire Training Ranges"; Chemosphere, 63, 1280, 2006.

[43] Dubé, P., Thiboutot, S., Ampleman, G., Marois, A. and Bouchard M., "Preliminary Assessment of the Dispersion of Propellant Residues from the Static Live Firing of 105-mm Howitzer"; DRDC Valcartier TM 2005-284, March 2006.

[44] Walsh, M.R., Taylor, S., Walsh, M.E., Bigl, S., Bjella, K., Douglas, T., Gelvin, A.B., Lambert, D., Perron, N.M. and Saari, S.P., "Residues from Live-fire Detonation of 155-mm Howitzer Rounds"; ERDC/CRREL TR 05-14, July 2005.

[45] Ampleman, G., Thiboutot, S., Marois A., Gamache, T., Poulin, I, Diaz, E., Quémerais, B., Melanson, L., "Analysis of Propellant Residues Emitted During 105-mm Howitzer Live Firing at the Muffler Installation in Nicolet, Lac St-Pierre, Canada"; DRDC Valcartier, TR 2007-514, December 2007.

[46] Ampleman, G., Thiboutot, S., Marois, A., Gagnon, A. and Gilbert, D., "Evaluation of the Explosives Residues Emitted During 105-mm Leopard Tank Live Firing and Sampling of Demolition Ranges at CFB Gagetown, Canada"; DRDC Valcartier, TR 2007-514, January 2008.

[47] Walsh, M.R., Walsh, M.E., Ramsey, C.A., Rachow, R.J., Zufelt, J.E., Collins, C.M., Gelvin, A.B., Perron, N.M. and Saari, S.P., "Energetic Residues Deposition from 60-mm and 81-mm Mortars"; ERDC/CRREL TR 06-10, May 2006.

[48] Thiboutot, S., Ampleman, G., Marois, A., Gagnon, A., Gilbert, D., Tanguay, V. and Poulin, I., "Deposition of Gun Propellant Residues from 84-mm Carl Gustav Rocket Firing"; DRDC Valcartier TR 2007-408, December 2007.

This page intentionally left blank.

Annex A

FILES ATTACHED ON COMPACT DISK

This page intentionally left blank.

List of symbols/abbreviations/acronyms/initialisms

ASQG	Agricultural Soil Quality Guideline
BG	Background Sample
BGL	Background Level
CBO	Canadian Base Operators
CCME	Canadian Council of Ministers of the Environment
CFB	Canadian Forces Base
CRREL	Cold Regions Research and Engineering Laboratory
DCC	Defence Construction Canada
DGE	Director General Environment
DLE	Director Land Environment
DND	Department of National Defence
DOD	Department of Defense
DRDC	Defence Research & Development Canada
DRDKIM	Director Research and Development Knowledge and Information Management
EL	Environmental Laboratory
EM	Energetic Materials
ERDC	Environmental R&D Center
GPS	Global Positioning System
HPLC	High Pressure Liquid Chromatography
ICP/MS	Inductively Coupled Plasma /Mass Spectrometry
INRS	Institut national de la recherche scientifique
ISQG	Industrial Soil Quality Guideline
LFC	Land Force Command
LFCA TC	Land Force Central Area Training Centre
MRTA	Meaford Range Training Area
MTSCM	Militia Training and Support Centre Meaford
NDHQ	National Defence Headquarters
OB/OD	Open Burning/Open Detonation
PAH	Polycyclic Aromatic Hydrocarbons

ppb	Parts per billion
ppm	Parts per million
QA/QC	Quality Assurance/ Quality Control
R&D	Research & Development
S	Soil Sample
SERDP	Strategic Environmental R&D Program
TTCP	The Technical Cooperation Program
UXO	Unexploded Ordnances

Distribution list

Document No.: DRDC Valcartier TR 2008-390

LIST PART 1: Internal Distribution by Centre

1	Director General
1	Head EM section
3	Document Library
1	Dr. G. Ampleman (author)
1	Dr. Sonia Thiboutot (author)
1	Mr. André Marois (author)
1	Ms. Annie Gagnon (author)
1	Dr. S. Brochu
1	Dr E. Diaz
1	Dr Isabelle Poulin
1	Ms. S. Villeneuve
13	TOTAL LIST PART 1

LIST PART 2: External Distribution by DRDKIM

1	Library and Archives Canada
1	DRDKIM (pdf file)
1	Director Ammunition Program Management-4 101 Colonel By Drive, 18 NT,Ottawa, Ontario, K1A 0K2
2	Director General Environment, C/O Ms. Elise Lemoyne,ADM(IE)/DGE, 101 Colonel By Drive, 18 NT,Ottawa, Ontario, K1A 0K2
3	Director Land Environment, C/O Ms. Katie Vint, DLE 3-5, Land Forces Command, 101 Colonel By Drive, 18 NT, Ottawa, Ontario, K1A 0K2
1	Director Science Technology Land-3, Mr. Craig A. Maskell, DSTL, 305 Rideau Street, Ottawa, Ontario, K1A 0K2
4	Mr. Ted Keunecke, Environmental Officer, LFCA TC Meaford 139152 Grey Road 112, RR1, Meaford, Ontario, N4L 0A1
13	TOTAL LIST PART 2

26 TOTAL COPIES REQUIRED

This page intentionally left blank.

DOCUMENT CONTROL DATA

(Security classification of title, body of abstract and indexing annotation must be entered when the overall document is classified)

<table>
<tr><td colspan="3">1. ORIGINATOR (The name and address of the organization preparing the document. Organizations for whom the document was prepared, e.g. Centre sponsoring a contractor's report, or tasking agency, are entered in section 8.)

Defence R&D Canada – Valcartier
2459 Pie-XI Blvd North
Quebec (Quebec)
G3J 1X5 Canada</td><td colspan="2">2. SECURITY CLASSIFICATION (Overall security classification of the document including special warning terms if applicable.)

UNCLASSIFIED</td></tr>
<tr><td colspan="5">3. TITLE (The complete document title as indicated on the title page. Its classification should be indicated by the appropriate abbreviation (S, C or U) in parentheses after the title.)

Evaluation of soil contamination by explosives and metals at the Land Force Central Area Training Centre (LFCA TC) Meaford, Ontario (Phase I):</td></tr>
<tr><td colspan="5">4. AUTHORS (last name, followed by initials – ranks, titles, etc. not to be used)

Ampleman, G.; Thiboutot, S.; Marois, A.; Gagnon, A.;</td></tr>
<tr><td colspan="2">5. DATE OF PUBLICATION (Month and year of publication of document.)

May 2009</td><td colspan="2">6a. NO. OF PAGES (Total containing information, including Annexes, Appendices, etc.)

104</td><td>6b. NO. OF REFS (Total cited in document.)

48</td></tr>
<tr><td colspan="5">7. DESCRIPTIVE NOTES (The category of the document, e.g. technical report, technical note or memorandum. If appropriate, enter the type of report, e.g. interim, progress, summary, annual or final. Give the inclusive dates when a specific reporting period is covered.)

Technical Report</td></tr>
<tr><td colspan="5">8. SPONSORING ACTIVITY (The name of the department project office or laboratory sponsoring the research and development – include address.)

Defence R&D Canada – Valcartier
2459 Pie-XI Blvd North
Quebec (Quebec)
G3J 1X5 Canada</td></tr>
<tr><td colspan="2">9a. PROJECT OR GRANT NO. (If appropriate, the applicable research and development project or grant number under which the document was written. Please specify whether project or grant.)</td><td colspan="3">9b. CONTRACT NO. (If appropriate, the applicable number under which the document was written.)</td></tr>
<tr><td colspan="2">10a. ORIGINATOR'S DOCUMENT NUMBER (The official document number by which the document is identified by the originating activity. This number must be unique to this document.)

DRDC Valcartier TR 2008-390</td><td colspan="3">10b. OTHER DOCUMENT NO(s). (Any other numbers which may be assigned this document either by the originator or by the sponsor.)</td></tr>
<tr><td colspan="5">11. DOCUMENT AVAILABILITY (Any limitations on further dissemination of the document, other than those imposed by security classification.)

Unlimited</td></tr>
<tr><td colspan="5">12. DOCUMENT ANNOUNCEMENT (Any limitation to the bibliographic announcement of this document. This will normally correspond to the Document Availability (11). However, where further distribution (beyond the audience specified in (11) is possible, a wider announcement audience may be selected.))

Unlimited</td></tr>
</table>

13. ABSTRACT (A brief and factual summary of the document. It may also appear elsewhere in the body of the document itself. It is highly desirable that the abstract of classified documents be unclassified. Each paragraph of the abstract shall begin with an indication of the security classification of the information in the paragraph (unless the document itself is unclassified) represented as (S), (C), (R), or (U). It is not necessary to include here abstracts in both official languages unless the text is bilingual.)

This work describes the first evaluation of the impacts of the live firing training at the Land Force Central Area Training Centre (LFCA TC) Meaford, Ontario (Phase I). This study was conducted in September 2007 by DRDC Valcartier for Director Land Environment (DLE) to evaluate soil contamination by explosives and metals. In parallel, the Institut national de la recherche scientifique (INRS) conducted sampling and analysis of surface water and groundwater for metals and explosives and produced a separate report describing their results. In our study, most of the ranges at LFCA TC Meaford were sampled during the September 2007 campaign. Seventeen ranges were sampled to evaluate the explosives and/or metals contamination. More precisely, at the small arms ranges, skeet range, artillery firing positions, anti-tank, grenade and other ranges, 135 soil samples were collected and analysed, including 79 for energetic materials, 56 for metals and seven for polycyclic aromatic hydrocarbons (PAHs) analyses. Surface and groundwater samples (35) were collected by INRS, analysed by DRDC Valcartier and revealed no energetic materials. Twenty soil background samples were taken for the metals evaluation for comparison purposes. Soil samples collected from Apeldorn, Cambrai, Ortona, Paardeburg Anti-tank, the Urban Assault and Skeet Ranges, as well as all the small arms ranges: Gully, Alpha and Gravenstafel Ridge; were analysed for metals contamination. Metal analyses were done using Inductively Coupled Plasma /Mass Spectrometry (ICP/MS) and explosives concentrations were determined using the High Pressure Liquid Chromatography (HPLC) Method EPA 8330b. Results showed that some firing positions are contaminated by energetic materials at low concentrations. Surprisingly, some firing positions contained metals at values higher than the industrial human health risk threshold criteria of the Canadian Council of Ministers of Environment (CCME). Tank positions in Cambrai are highly contaminated by selenium. All the small arms ranges contained lead at high concentrations while the skeet range contained PAHs at values higher than the CCME industrial threshold criteria. More work is needed to clarify the situation and will be conducted during Phase II. This report describes the sampling and the results obtained during this study.

Ce travail décrit la première évaluation des impacts de l'entraînement par tir réel faite au Centre d'instruction du secteur centre de la force terrestre (CISCFT) à Meaford, en Ontario (Phase I). Cette étude a été effectuée en septembre 2007 par RDDC Valcartier pour le Directeur de l'environnement de la force terrestre (DEFT) afin d'évaluer la contamination des sols par les explosifs et les métaux. En parallèle, l'Institut national de la recherche scientifique (INRS) a effectué l'échantillonnage de l'eau de surface et souterraine pour les métaux et les explosifs et a produit un rapport séparé où leurs résultats sont décrits. Dans notre étude, la plupart des secteurs du CISCFT Meaford ont été échantillonnés pendant la campagne de septembre 2007. Dix-sept secteurs ont été échantillonnés pour évaluer la contamination par les explosifs et/ou par les métaux. Plus précisément, dans les secteurs de petit calibre, de tir au pigeon d'argile, de positions de tir d'artillerie, d'anti-char, de grenade et autres, 135 échantillons de sol ont été recueillis et analysés incluant 79 pour les matériaux énergétiques, 56 pour les métaux et sept pour les hydrocarbures aromatiques polycycliques (HAPs). Des échantillons d'eau de surface et d'eau souterraine (35) ont été recueillis par l'INRS, analysés par RDDC Valcartier et n'ont révélé aucun matériau énergétique. Vingt échantillons de sols d'arrière-plan ont été recueillis pour analyser les métaux et servir de comparaison. Les échantillons de sols ramassés dans les secteurs Apeldorn, Cambrai, Ortona, anti-char Paardeburg, Assault Urbain et tir au pigeon d'argile aussi bien que dans tous les secteurs de petits calibres Gully, Alpha, Gravenstafel Ridge ont été analysés pour la contamination par les métaux. Les analyses de métaux ont été effectuées par plasma inductif couplé/spectrométrie de masse (PIC/SM) et les concentrations d'explosifs ont été déterminées par la méthode de chromatographie liquide haute pression (CLHP) EPA

8330b. Les résultats ont montré que quelques positions de tir sont contaminées par des matériaux énergétiques à des concentrations basses. Étonnamment, quelques positions de tir contenaient des métaux à des valeurs plus élevées que le critère de niveau industriel pour les risques à la santé humaine du Conseil Canadien des Ministres de l'Environnement (CCME). Les positions des chars dans Cambrai sont très contaminées par le sélénium. Tous les secteurs de petits calibres contiennent du plomb à des concentrations élevées alors que le secteur de tir au pigeon d'argile contient des HAPs à des valeurs plus élevées que le critère industriel CCME. Plus de travail est nécessaire pour préciser la situation et sera accompli durant la phase II. Ce rapport décrit l'échantillonnage utilisé ainsi que les résultats obtenus durant cette étude.

14. KEYWORDS, DESCRIPTORS or IDENTIFIERS (Technically meaningful terms or short phrases that characterize a document and could be helpful in cataloguing the document. They should be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location may also be included. If possible keywords should be selected from a published thesaurus, e.g. Thesaurus of Engineering and Scientific Terms (TEST) and that thesaurus identified. If it is not possible to select indexing terms which are Unclassified, the classification of each should be indicated as with the title.)

characterization, explosives, soil, metal, contamination

Defence R&D Canada

Canada's Leader in Defence
and National Security
Science and Technology

R & D pour la défense Canada

Chef de file au Canada en matière
de science et de technologie pour
la défense et la sécurité nationale

DEFENCE DÉFENSE

www.drdc-rddc.gc.ca